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Map reading and military sketching

Paul Stanley Bond

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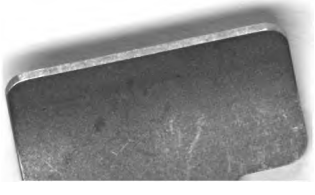

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MAP READING

AND

MILITARY SKETCHING

A Complete Practical Exposition of Map Reading and Map Making for Military Purposes

---

BY

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PREFACE.

Map making, including military map reading, is a practical art. Proficiency can be acquired only by practical experience.

As in all other lines of endeavor there are certain methods, developed from the experiences of many persons extending over many years, which have come to be recognized as constituting "good practice" in military sketching. A few simple instruments, simplified also in long experience as to what is necessary and what is superfluous or an incumbrance, are now generally recognized as forming the most efficient equipment for the sketcher.

The purpose of this volume is to set forth the methods of good practice—the manner in which the accepted instruments are used to attain the results desired.

With this purpose in view the text is arranged as a series of lessons of suitable length, progressing logically from the simple fundamental operations to the complete procedure of making a sketch. Each lesson includes the principles or common sense rules on which procedure is based, which are visualized by practical examples; with instructions for work in the field.

But the military man has not alone to learn how to do things himself. He must acquire the ability to impart his knowledge to others, to train his officers and men to perform *their* duties.

The text has accordingly been prepared for the use of the individual studying alone, and for both instructor and students of a class.

Practical experience, and lots of it, is necessary to proficiency. But it should be based on a prior knowledge of good practice. Otherwise the student will waste much of his time making mistakes which others have made before him, which are pointed out herein, and which accordingly may and should be avoided.

FOR THE AUTHORS,
P. S. BOND,
Lt.-Col. Corps of Engineers.

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MAP READING AND MILITARY SKETCHING.

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MAP READING AND MILITARY SKETCHING.

INTRODUCTION.

Map reading and map making are of such importance in all military operations that no officer's education can be considered complete or even satisfactory, unless he has a thorough *practical* knowledge of these essential subjects.

The game of war is played on a map. All military operations, from those of a great army to those of a small patrol, are planned and executed by the aid of maps. In war the map is as much in evidence as the rifle or machine gun. No plans could be prepared, and few reports would be intelligible, except for maps. Without them a great army would be almost helpless. In time of peace much of the tactical instruction of the army is given on a map. A thorough understanding of maps, therefore, is one of the chief fundamentals of a military education.

But the map is not exclusively a military instrument. There are few persons who have not had occasion to consult maps at some time or other. Many professional and business men consult them frequently; travelers by rail or automobile have constant need of them.

Map reading and map making constitute an excellent training for the mind. They serve to develop one's faculties of observation and logical reasoning to as great an extent as any other form of instruction. Accordingly such training will not be wasted, whatever may be the future activities of the student. It is training readily acquired also, because map reading and map making are both easy and pleasant subjects.

Contrary to popular belief there is nothing mysterious about maps. They are made on common sense principles, and any person of average intelligence can learn both to read and make them. No knowledge of higher mathematics is required. Moreover the study will be found both helpful and intensely interesting. It is very important that this be impressed on the student's mind at the outset.

The subject of maps naturally divides itself into two parts, map reading and map making. Of these, map reading logically comes first. Most junior officers will be called upon to prepare sketches from time to time. But all officers of every rank will be called upon to read maps almost daily during military operations.

However, if necessary to take advantage of good weather for outdoor instruction in sketching, especially in localities in the northern part of the country, the latter course may be begun before the instruction in map reading is completed. For example, the subjects of the curvature of the earth, latitude and longitude, map co-ordinates, profiles, visibility, aerial photography and map reproduction, are not essential preliminaries to the course in sketching, and may be studied later, during the winter.

The instructor should obtain for display to the class a number of maps for various purposes and to various scales. Military sketches of various kinds should likewise be exhibited. These may be made by the instructor, reproduced from existing maps, or taken from some of the many textbooks on sketching.

The U. S. Geological Survey maps (1/62,500) may be obtained from the Geological Survey in Washington. It is best to obtain a map of the locality of the institution or some nearby section. The *Plans directeurs* and other maps used in France may be obtained (in limited numbers) from the War Department. Topographical maps of the vicinity of Gettysburg, Pa., on scales of 3″ and 12″ to the mile, may be purchased at a nominal cost from the Army Service Schools at Fort

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Leavenworth, Kansas. They will be especially useful for practical instruction in map reading and minor tactics.

For the solution of these practical problems in map reading one or more 12" (Gettysburg) maps on the wall or a table, or a 3" map for each two students, will be found quite satisfactory, and their cost is not great.

For the convenience of the students, and to avoid a multiplicity of maps, it is suggested that map reading problems be laid on the same maps that are used for tactical instruction.

As map reading is a practical art it is best taught by the solution of practical problems. These exercises will be more valuable and interesting if they have a military application. It is the military necessity for facility in the reading of maps that should be impressed upon the student. The lessons which follow contain a number of carefully selected practical problems and exercises in map reading, designed to illustrate the subject matter of the text, and test the student's knowledge thereof. The instructor may prepare any number of additional problems along the same lines, and may also require the students to prepare problems as part of their instruction.

Relief maps are of great assistance for instruction in map reading and sketching, and it is desirable to have some for display to the class. The sand table may also be used to portray ground forms, streams being shown in blue, and contours by white thread. The construction of a simple relief map from a large scale topographical map (in layers of wax or cardboard) should be demonstrated to the students, if there be no time for them to make the map themselves.

The sand table is a form of relief map especially useful for military instruction, including that of the R. O. T. C. It may be used to great advantage in teaching this subject (Topography) as well as Musketry, Field Engineering and Minor Tactics. The sand table is, in fact, the basis of the system of practical instruction in Minor Tactics in this course. The method of reproducing a terrain in miniature on the sand table, and representing the important natural and cultural features, is accordingly set forth in detail in the beginning of the course in Minor Tactics. The students may be permitted to take part in this work, or at least to see a demonstration of it.

Ordinary school globes are useful for illustrating those portions of the text referring to the rotundity of the earth, latitude and longitude, etc.

In order to impress the lessons on the students' minds they should be required to keep notes of all problems solved, and of interesting points brought out by the instructor in recitation or conference, not covered in the text.

Students who prepare their lessons in advance and show an aptitude for the subject may be utilized as assistant instructors. This is stimulating to their pride and produces excellent results.

The lessons following are arranged in a logical sequence, and are designed to present to the students the fundamentals of map reading and sketching, without confusing their minds with unnecessary, abstruse or petty details. Once these fundamentals are grasped an understanding of the subject is assured, and the solution of practical problems becomes easy and pleasant.

However, the order of the subject matter in the lessons may be varied according to the views of the instructor and the circumstances attending the instruction. If desired one lesson may be divided into two days of instruction or certain subjects may be omitted. The order and arrangement herein, while regarded as logical for the average organization, are in no sense mandatory. The important points are that everything essential has been included, and that the lessons as laid out are in accordance with general schedules based upon the instructions of the War Dept.

If the conditions in the locality are such that no opportunity to make complete military sketches outdoors is afforded, relatively more time may be devoted to map reading and the fundamental operations in sketching, leaving the making of complete sketches until the time of the summer encampment.

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Each of the lessons following corresponds to a day of theoretical instruction. The corresponding practical periods should be devoted to demonstrations and the solution of practical problems. The practical problems following each lesson are intended to illustrate the important features of the lesson, and are arranged approximately in order of relative importance. During the time allotted to practical work the instructor should demonstrate (solve in the presence of the students) each of these problems in succession, and then cause the students to solve a similar problem, making necessary record in their note books. As many problems should be solved as the aptitude of the students allows. But it is far more important that they be solved *properly* than that they be solved *rapidly*.

Prior to the opening of the course the instructor should assure himself that all maps, materials and equipment necessary are at hand, or that arrangements have been made to obtain them.

The making of precise or highly accurate maps is one of the fine arts, involving the use of very complicated instruments and methods. It is unnecessary that the average military man should be familiar with these. The officer with the combatant forces must be able to read the maps ordinarily employed in war with rapidity and accuracy. And he should be able to execute a military sketch sufficiently accurate for the needs of his immediate superiors. Accordingly all references to the instruments and methods of precise surveying have been omitted from the course which follows, as they would tend only to confuse the student and to make a simple matter seem abstruse. The aim of the instructor at all times should be to make map reading and sketching as simple and easy as possible. The close of the course in map reading should find every student confident in his ability to interpret all the information conveyed by any ordinary topographical map.

MAP READING.

FIRST LESSON.

Maps and Sketches Defined.

A *map* is a graphical representation to scale, on paper, of a definite portion of the earth's surface. The expression "to scale" means that a certain distance on the map, one inch for example, always represents a certain distance on the ground, as one mile. It also means that all points on the map are in the same relative horizontal position as the points on the ground which they represent. Maps are made by means of measuring instruments of great precision, and are accordingly accurate, the degree of accuracy usually depending upon the purpose for which the map is employed.

A *military sketch* differs from a map in that it is made with very simple instruments, in a short time, and is hence rougher in appearance and less accurate than a formal map. It is in effect, a crude map.

A map accordingly is a picture and description of an area of ground, on a small scale. A good map conveys more information than a volume of description. In fact no amount of verbal description can possibly convey the information concerning the terrain that is exhibited in a glance by a good map.

A map differs from an aeroplane photograph in that the information concerning the ground is conveyed by means of symbols known as conventional signs. So far as practicable these symbols resemble the objects they represent, but in most cases are greatly simplified and conventionalized. A knowledge of what these symbols mean is necessary to a proper understanding of the map. In addition to the symbols the names of particular localities and a few descriptive notes may also appear on the map.

Map Reading.

Map reading is the art of interpreting or understanding the information conveyed by a map. It is not sufficient that the reader should merely understand the meaning of the symbols employed. A complete map should convey to a practical reader a mental conception, a real picture of the ground which it represents. The value of

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the map to its user depends on the vividness with which he pictures in his mind the actual appearance of the ground represented, and on the amount of detailed information which he can derive from the map.

The essential items of information derived from the reading of a map are *distance, direction, natural* and *artificial features* (as indicated by *conventional signs*), *elevations* and *ground forms*. Each of these will be discussed in detail.

Classification of Maps According to Use.

Maps are of various classes and scales (size) according to the purpose for which they are to be used, and the nature and amount of the information they convey. A simple road map, for example, displays merely a number of lines representing the positions of the roads, and dots showing the locations of the towns along them. Such a map conveys no picture of the ground—it is not intended for that purpose. A complete topographical map, on the other hand, conveys to one who understands it, a birdseye view of the countryside, the hills, ridges, streams and valleys, the roads, buildings, fences, crops, etc.

A *military map* is one which conveys such information as may be useful for military purposes. There are of course, various classes of military maps according to the particular information to be exhibited.

The classification of maps may be illustrated by an example. Suppose it were desired to plan a movement of troops by rail from the Atlantic to the Pacific Coast. There would be required for this purpose a map on a sheet of moderate size, which could be comprehended in one glance, showing the principal railroads and their connections, the boundaries of the states, the two coast lines and the location of the principal cities with reference to the railroads. Such a map to be represented on a single sheet must be of small scale. It would be far from a complete map of the territory represented, yet it would convey all the information necessary for the purpose for which it was used. Unnecessary details would be merely confusing.

Suppose, however, an officer were given the problem of locating lines of intrenchment for the defense of the city of Washington against an attack from the south. He would require a map on a fairly large scale, and hence in several sheets, showing the city and the adjacent territory with all its hills, valleys, streams, roads, railroads and buildings, because all of these features would be of importance for defensive purposes. And in addition, to grasp the situation as a whole, he would require a map in a single sheet on a smaller scale, showing in outline the location of Washington and the surrounding towns, the principal rivers, the main roads and railroads, and *the areas covered by each of the larger sheets* in their proper relative positions. This latter map would be what is called an *index map* or *reference map*.

In the two cases cited it will be noted that the map appropriate to either would be entirely useless in the other, because of their difference in scale and the nature of the information conveyed.

Maps are also classified as *standard* and *special*. Standard maps are those ordinarily prepared in time of peace and issued in large numbers for general use. Special maps are those prepared for a special purpose, to show special military details not given on the general maps. They may be independent surveys, or may consist of additional data placed on some standard map. Examples of such special maps would be those exhibiting the " Order of battle " (location of our own troops), " Enemy order of battle," " Graphic summary of intelligence," etc.

The standard maps employed in the field will be chiefly those produced in time of peace by the civil agencies of the government.

Map Scales.

The first feature of a map to be considered is its *scale*. The scale of a map is the ratio between any (which is *every*) horizontal distance on the map and the same horizontal distance on the ground. Thus if two houses are 1 inch distant from each other on the map and 5000 inches on the ground, the scale of the map is 1 to 5000, or as a fraction, 1/5000. This ratio is known as the *representative frac-*

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tion (R. F.) of the map. It is always written with a numerator of unity. Thus if 3 inches on the map represents 90,000 inches on the ground the R. F. would be 1/30,000 and not 3/90,000. A map is said to be on a *large* scale when its R. F. is large (*i. e.,* when the denominator is *small*) and vice versa. Thus a map with a R. F. of 1/1000 is a very large scale map, and one with a R. F. of 1/10,000,000 is a very small scale map.

The scale of a map is a matter of great importance to both the user and maker of the map. Without a scale all distances on the map would be unknown, hence the reader seeks first to ascertain the scale by which he must measure the distances he wishes to know. The scale of a map also fixes its *size* relative to the area of ground which it represents, and hence the amount of detailed information concerning that ground which can be placed on the map. For example a map on a scale of 1 inch equals 25 feet (R. F. 1/300) could show the actual size of individual buildings, even the width of the sidewalks in front of them, and the location of each separate tree along the roads. A map on a scale of 1/200,000 would not show individual buildings at all, sidewalks and trees would not be thought of. The roads would appear merely as lines, and woods in outline only. The first map would serve the purposes of a landscape architect, the second those of a general disposing the large units of his command.

Proper scale, how determined. It will be apparent then that the proper scale for any map is determined by the purpose for which the map is to be employed, as fixing the amount of detailed information to be conveyed. For reasons of economy, in order that map sheets may be no larger than necessary and yet cover as much territory as possible, the scale of any map should be the least that which will permit the necessary details to be shown. A map of the United States on a scale of 1/1000 for example, would be perfectly useless *as a map of the United States.* It would take an hour to walk across it.

The time required to map a given area increases rapidly with the amount of detail shown. The cost of making and distributing maps increases with the number of sheets required to cover a given area. Much time is lost if it is necessary to use several large sheets when one small one would serve even better. Accordingly the scale of any map should always be the least that will serve the purposes of the user.

For use in the field in campaign, very large map sheets are objectionable for the same reason that a large newspaper is objectionable in an open car. 18 x 24 inches is a convenient size, and anything larger than 24 x 36 inches is usually a nuisance. In an office, where walls and tables are available for the display of maps, much larger sheets are permissible. Map sheets are usually printed in relatively small sizes, and large maps for wall display are made up by piecing together several sheets.

The standard Geological Survey Sheets are 20 x 16½ inches—a very convenient size for field use.

In the field, maps may be carried in leather cases with celluloid faces which permit the map to be read without removing it from the case. These are convenient for carrying the maps and protecting them from the weather, wear and tear. As the map sheet is usually larger than the case, it must be folded for insertion, the desired section of the map being placed where it can be read.

The representative fraction completely determines the scale of the map. But its use involves a calculation, often a laborious calculation, of every distance measured on the map. Thus if the R. F. be 1/100,000 we know that 1 inch on the map represents 100,000 inches on the ground. As we do not measure ground distances in inches we must first reduce this to feet, and then to miles to obtain a definite idea of the ground distance represented. The scale will be simpler to use if it expresses the relation between map distances in their usual units (inches), and ground distances in *their* usual units (feet, yards or miles). Examples of such scales, as usually expressed are:

1 inch equals 200 feet (R. F. 1/2400).
1 inch equals 1000 yds. (R. F. 1/36,000).
1 inch equals 1 mile (R. F. 1/63,360).

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Graphical scales. Another method, permitting still more rapid determination of ground distances from map distances, is the *graphical scale.* This is a measuring device printed on the map, in which ground distances, in the usual units, are shown to the scale of the map. For example suppose the scale of the map to be 1 inch equals 1 mile (R. F. 1/63,360) and we wish a graphical scale reading to 250 yards. 1000 yards on the map equal 1000/1760 of 1 inch, or about 0.57 inch. We lay off several intervals of .57 inch, each of which represents 1000 yards on the ground, and one interval to the left (known as an *extension* to the scale) divided into four equal parts, each representing 250 yards. The scale would then appear as in Plate 1.

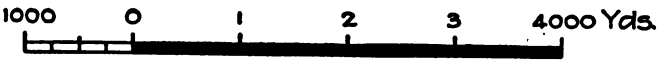

PLATE 1.—Graphical Scale, 1″ = 1 mile.

To convert any map distance to its corresponding ground distance, copy the graphical scale on a slip of paper and apply it to the map distance to be measured, or take off the map distance on a slip of paper or dividers and apply it to the graphical scale.

It will be noted that the scale proper reads from *left* to *right* and the extension from *right* to *left.* To take off a distance such as 3750 yards lay a strip of paper along the scale, make marks at 3 on the main scale, and at the 3rd division to the left of the zero (3×250 equals 750) on the extension. The advantage of an extension reading to the left is best appreciated on a large scale map reading to small distances such as 10 or 100 yards.

For measuring distances not in a straight line the graphical scale is somewhat inconvenient. It is often necessary in military operations to determine the distance between two points along a winding road. This may be done by taking off all the straight sections in succession on a strip of paper and applying the total to the scale, or by stepping along the road with a pair of dividers opened to some decimal interval as 100 or 1000 yards. A more rapid method is by means of a *map measure,* which consists of a small wheel which may be rolled along the road, and a dial which records the distance in inches. The ground distance may then be calculated, or the map measure rolled back to its zero along the graphical scale, the distance it covers being noted.

A graphical reading scale should always be plainly marked to show the *ground* units in which it is graduated.

As an ordinary map is a plane surface, all distances represented upon it are *horizontal,* or *level* distances. Vertical distances or elevations, and ground slopes are represented by the conventional signs known as *contours,* to be discussed later.

The representative fraction, and a graphical scale in the usual units should be placed on every map or sketch. If no scale be exhibited, the R. F. may be determined by measuring the distance between two well defined objects, on the map and on the ground. Suppose, for example, that the distance from *A* to *B* on the ground is measured and found to be 1200 yards. The map distance is found to be about 11/16 inch. Then the R. F. is 11/16÷(1200×36) equals 1/62,836. This is what would be called an incommensurable scale, and no map, except by error, was ever made with such a R. F. Our measurements were evidently approximate only. If the map is a Geological Survey map (with the scale torn off) we may assume that its R. F. is 1/62,500, as that is the scale always employed by the Geological Survey. If it is a military map its scale is probably 1 inch equals 1 mile (R. F. 1/63,360). Having the R. F. a graphical scale of yards or miles is readily constructed as heretofore explained. An erroneous scale on a map is corrected as above, or by comparing the map with the other sheets of the same issue.

Maps of continental Europe are usually on the French metric system, the unit for ground distances being the kilometer, which is about ⅝ of our mile. Some of

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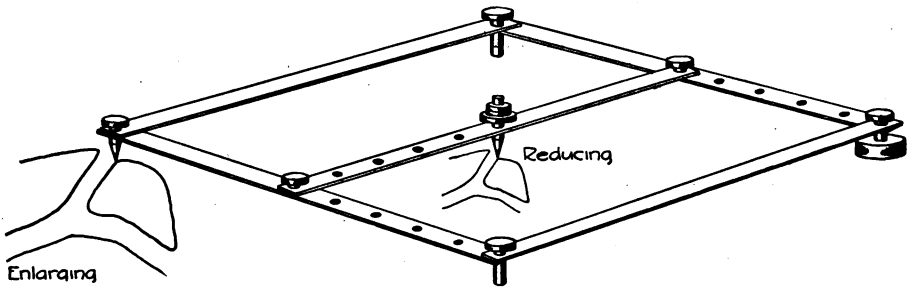
the maps used by the American Expeditionary Forces in the late war were provided with graphical scales of both miles and kilometers.

Changing the scale of a map. A problem occasionally confronting the military man is to reduce a number of maps on different scales to a common scale in order that they may be combined into one map. This is readily accomplished by photography, the various maps being reduced or enlarged until a certain distance, such as 10 miles, on their original graphical scales, is of the length desired for the combined map. Another and very laborious method is that of "equivalent squares." The map whose scale is to be changed is divided into a number of squares, with sides running north and south and east and west, each measuring some definite distance such as 1 mile or 1000 yards on a side. A "grid" is then prepared on a blank sheet of paper, consisting of squares of the *same ground unit* (1 mile or 1000 yards) to the *desired* map scale. These squares will be larger or smaller than those on the map to be altered. The topography in each square of the map is then transferred by eye, and such measurements as necessary, to the corresponding blank square. Still another method of changing the scale of a map is to re-draw it with a *pantograph*, an instrument having two movable points which travel in unison, drawing lines parallel to each other and having any desired ratio of length. One point is passed over the lines of the map and the other reproduces them on the new scale. Small items of topography may be transferred from one map to another of different scale by the use of *proportional* dividers.



THE PANTOGRAPH

Relation of scale to area. The area of any rectangle, whether on the ground or on the map, is the product of its two sides. Thus a rectangle 2 miles wide and 3 miles long (on the ground) has an area of $2 \times 3 = 6$ sq. miles. On a map with a scale of 2 inches equal 1 mile this rectangle would be represented by a map rectangle 4 inches wide and 6 inches long, having an area of 24 sq. inches. On a map of half this scale, or 1 inch equals 1 mile, the corresponding rectangle would measure 2 inches wide and 3 inches long and the map area would be $2 \times 3 = 6$ sq. inches. This same relation would exist for any ground area and its equivalents or representations on the two maps. Thus we perceive that in reducing the scale of a map to $\frac{1}{2}$ we reduce its area to $\frac{1}{4}$. If we double the scale we quadruple the area. Thus the areas of any one piece of ground on two maps of different scales are proportional to the squares of the representative fractions of the maps. A map of a certain area on a scale of 2 inches equal 1 mile is four times as large as one of the same area on a scale of 1 inch equals 1 mile. A map of the area on a scale of 3 inches equal 1 mile is nine times as large as one on a scale of 1 inch equals 1 mile.

Scales of Military Maps.

While maps are made on a great variety of scales there is, as we have pointed out, a scale appropriate for each purpose for which a map is used. It is very desirable that the number of different scales be as small as possible, and *standardized*, both as a measure of economy in map making, and to accustom us to the use of maps of a certain scale for a certain purpose.

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For the military man tactical operations require maps of relatively large scale, and strategical studies maps of relatively small scale. In Europe maps on various scales were available. In the United States the only satisfactory map for tactical uses is that of the Geological Survey on a scale of 1/62,500 or approximately 1 inch equals 1 mile.

The following scales are appropriate for various military uses:

12 inches equal 1 mile..... Instruction in map reading, war game and map maneuvers.

6 inches equal 1 mile..... Same as above. Also for military position or area sketches.

3 inches equal 1 mile, or 1/20,000... Tactical problems. Map reading. Fire control and artillery uses. Tactical map for stabilized warfare. Road sketch.

1 inch equals 1 mile, or 1/62,500.... Tactical problems (large units). Tactical map for open warfare.

1/200,000 ..... Strategical map. General operations. Supply. Should cover entire theatre of war.

1/500,000; 1/1,000,000 and smaller.. General strategical maps.

The following scales have been adopted as standards for future use for various military purposes:

1 : 20,000 (about 3 in. = 1 mile)..... Fire control, artillery objectives, fortified and training areas, enemy works, etc.

1 : 62,500 (about 1 in. = 1 mile)..... Tactical map for general use in open warfare. Troop movements.

1 : 250,000 ..... Strategical map.

1 :500,000
1 : 1,000,000 } ..... General maps.

1 : 2,500,000
1 : 7,000,000 } ..... Geographic maps.

In actual warfare, of course, the maps actually used will be those that are available, regardless of any regulations that may have been promulgated in time of peace.

Notes.

There should be on hand for exhibit to the students a number of maps and sketches, on different scales and for different purposes. By the aid of these the instructor may indicate to his students the maps appropriate for various tactical and strategical purposes, the relation of scale to the purpose of the map, etc.

The students should note the great amount of verbal description required to convey the same information as a few lines on the map, and how unsatisfactory such description would be.

Scale problems are of great importance, and should be repeated occasionally throughout the course in map reading. Students should devise scale problems of their own.

The relation of scale to the purpose of the map and the detail to be shown is also of great importance.

The method of changing the scale of a map by "equivalent squares" may be illustrated on the blackboard. The instructor should draw some simple topography covering two to four squares, and cause a student who has an aptitude for drawing to reduce the scale in the presence of the other students. The pantograph may be exhibited if one is available.

Practical Problems.

1. Demonstrate and cause students to measure distances between various points on the 12-inch (equals 1 mile) map, using a slip of paper and dividers. Measure distances along a winding road with slip of paper, dividers and map measure.

2. The distance between *A* and *B* on a map, R. F. 1/6000, is 1½ inches. What is the distance on the ground?

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Solution: 1½ inches on the map represents 1½ × 6000 equals 9000 inches on the ground, 9000 divided by 36 equals 250 yards.

3. The distance between *A* and *B* on a map is 1½ inches, on the ground it is 750 yards. What is the R. F. of the map?

Solution: 750 yards is 750 × 36 equals 27,000 inches. Hence, 1 inch on the map represents 27,000 divided by 1½ equals 18,000 inches on the ground, and the R. F. is hence, 1/18,000.

4. The R. F. of a map is 1/31,680. (a) How many miles are represented by 1 inch? (b) Construct a scale to read miles with an extension to read hundreds of yards; (c) How should the extension be graduated?

Solution: (a) 1 mile is 5280 × 12 equal 63,360 inches. 1 inch on the map represents 31,680 inches on the ground. 31,680 divided by 63,360 equals ½. Hence, 31,680 inches is ½ mile, represented by 1 inch on the map. (This would usually be expressed as 2 inches equal 1 mile.) (b) 1 mile on the graphical scale will be 2 inches. As there are 1760 yards in a mile, one yard on the map will be 2 inches divided by 1760 = 0.00116 inches and 100 yards will be 0.00116 inches × 100 equals 0.116 or about 0.12 inch. (c) If all distances up to 1 mile are to be read to the nearest 100 yards the extension to the scale should be graduated up to 1700 yards.

5. On a foreign map it is found that 1 kilometer on the graphic scale measures 0.4 inch. (a) What is the R. F.? (b) Does this seem reasonable?

Solution: (a) 1 meter is approximately 40 inches. Hence, a kilometer is 40,000 inches in the ground, and is found to be 0.4 inch on the map. The R. F. is hence, 0.4/40,000 equals 4/400,000 equals 1/100,000. (b) Yes, 1/100,000 is a R. F. commonly employed for maps. Had our solution given the R. F. as 1/99,000 we could safely assume that our measurement was only approximate, and take the R. F. as 1/100,000.

6. What would be a proper R. F. for a map of the U. S. to occupy a wall space about 6 feet wide?

Solution: The width or east and west dimension of the United States is about 3000 miles. On the map this would be the width or horizontal dimension. Accordingly 3000 miles must be represented by about 6 feet on the map. Hence, the R. F. would be about 6/3000 × 5280 equals 6/15,840,000 equals 1/2,640,000. The denominators of such small R. F. are usually in millions and half millions, hence, the nearest scale we could obtain would be 1/2,500,000, which map would be a little over 6 feet wide, allowing also for the two oceans and the borders of the map. A map with an R. F. of 1/3,000,000 would be the next smaller size, and would fit the available space.

7. A sketcher made a map on a scale of 3 inches equal 1 mile, assuming that his stride was 60 inches. Later he found his stride to be actually 64 inches. (a) What is the true R. F. of his map? (b) 3 inches on the map represents how many miles? (c) Is the map accurate?

Solution: (a) The sketcher finds that the distance on the ground is actually *greater* than he had supposed. Hence, the R. F. of his map is too *large* or his denominator, representing the ground distance, is too *small* in the proportion of 60 to 64 or 15 to 16. The assumed R. F. is 3/1 × 5280 × 12 equals 3/63,360 equals 1/21,120. To increase the denominator in the proportion of 15 to 16, divide by 15 and multiply by 16, giving 1/22,528 as the true R. F. (b) 3 inches on this map now represents *more* than 1 mile in the same proportion (15 to 16) or 1-1/15 miles, equals 1.0667 miles. This is an unsatisfactory scale, and if this were an accurate map it would have to be reduced to the proper scale to be combined with others. (c) The map would be accurate if the sketcher made no mistakes other than the one mentioned.

8. A certain map has a scale of 6 inches equal 1 mile. What would be the scale if the area of the map sheet were reduced to 1/16 its present size?

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Solution: The scales or R. F. of two maps are proportional to the square roots of the areas on the two maps representing the same ground area. The square root of 1/16 is ¼. Hence, in reducing the area to 1/16 we reduced the scale to ¼ what it was, or to 6/4 = 1½ inches to the mile.

9. (a) Construct a graphic scale to read feet with an extension to read inches for a map on a scale of ¾ inches equal 1 foot. (b) What is the R. F. of this map? (c) For what purposes might such a map be used?

Solution: (a) Each foot will be represented by ¾ inch and each inch by 1/12 of ¾ inch, or 1/16 inch. (b) The R. F. is ¾ divided by 12 or 1/16. This is also evident from (a) since 1 inch is represented by 1/16 inch. (c) Such a map, its scale being very large, might be used to lay out building plans, gardens or small parks, a tennis court, etc.

10. On a map with no scale shown the distance between the 30th and 31st parallels of latitude, shown on the map, is found to be 2⅓ inches. What is its R. F.?

Solution: The length of a degree of longitude (between two parallels) is about 69 miles. This is represented on the map by 2⅓ inches. Hence, 1 inch represents 69 divided by 2⅓ equals 29.6 miles, about. We may safely assume the scale to be 1 inch equals 30 miles. The R. F. is then $1/30 \times 5280 \times 12 = 1/1{,}900{,}800$.

11. A column of cavalry marches at a rate of 5 miles per hour. It is under orders to move from *A* to *B*. Which is the shortest route and how long will be required for the march?

Solution: Measure the length of each of the available routes with a map measure and note which is the shortest. Measure this again with the map measure and check against first reading, measuring a third time if the readings do not agree. Now roll the map measure back to zero along the graphical scale and note the distance covered. Suppose it to be 26½ miles. Then the time in hours required to march this distance is 26½ divided by 5 equals 5.3 hours or 5 hours, 18 minutes.

12. The map distance between two points on a map having an R. F. of 1/2400 is 16 inches. The distance between the same two points on another map is 20 inches. What is the R. F. of the second map?

Solution: The R. F. of the first map (1/2400) may be written as $1 \times 16/2400 \times 16$. As the ground distance remains the same while the map distance changes from 16 to 20, the R. F. of the second map may be written as $1 \times 20/2400 \times 16$, it being remembered that the numerator represents the map distance and the denominator the ground distance. Reducing this fraction to its simplest terms we have 1/1920 as the R. F. of the second map. The scale is *greater.*

13. The scale of a French map is 1 centimeter equals 1 kilometer. Construct a scale to read miles on this map.

Solution: Since 1 km. equals 100,000 cm. the R. F. of the map is 1/100,000. One mile on the ground is 63,360 inches, and on this map it is 63,360 inches divided by 100,000 equals 0.633 inches. Ten miles equal 6⅓ inches, which distance may be divided into 10 equal parts, each representing 1 mile.

14. The area of a certain park on one map is 16 sq. inches. On another it is 25 sq. inches. The scale of the first map is 1 inch equals 250 feet. What is the scale of the other?

Solution: The lengths (or widths) of the same park on the two maps are proportional to the square roots of the two areas, or as 4 to 5. Hence, if 250 feet on the first map is represented by 1 inch, the same distance on the second map is represented by 1¼ inches, and its R. F. is $1¼/250 \times 12 = 1/200 \times 12 = 1/2400$, and its scale is 1 inch = 200 feet.

15. A map on a scale of 6 inches equal 1 mile is to be reduced to a scale of 4 inches equal 1 mile by the method of "equivalent squares." The squares on the map will measure 6 inches on a side. Those of the grid for the altered scale will be 4 inches on a side, but any other dimensions *having the same ratio,* may be used

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as 9 and 6, 3 and 2. The instructor should demonstrate this process on the blackboard, part of the operation being performed in the presence of the class.

16. The R. F. of a certain map is 1/5280. What is its scale in miles per inch, in inches per mile, and in yards per inch?

Solution: One inch on the map equals 5280 inches on the ground. One mile on the ground equals 63,360 inches. Hence, the number of miles to the inch is 5280/63,360 equals 1/12, and the number of inches to the mile is 63,360/5280 equals 12. The number of yards per inch is 5280/36 equals 146⅔.

17. Construct a scale to read hours with an extension to read to ten minutes for marching infantry on a map having a scale of 1 inch equals 1 mile.

Solution: The average pace of infantry is found to be 2½ miles per hour. Hence, the length of one hour on the proposed scale will be 2½ miles or 2½ inches of the graphical scale of distances found on the map. The 10 minute intervals will be ⅙ of an hour, that is ⅙ of 2½ inches, or about 0.4 inch.

The following problems are similar to the problems of the same numbers whose solutions are given:

2. The distance between *A* and *B* on a map whose R. F. is 1/62,500 is 2½ inches. What is the distance on the ground in feet and inches?

3. The distance between *A* and *B* on a map is 1.6 inches. On the ground it is measured as 950 yards. What is probably the correct scale of the map and what was the error in the ground measurement?

4. The R. F. of a map is 1/20,000. How many miles are represented by 1 foot on this map. Construct a scale to read miles, with an extension reading tenths of a mile.

5. On a French map 1 kilometer is found to measure 0.32 inch. What is the R. F. of the map? Is this probably correct?

6. What would be the R. F. of a map of the United States to go under the glass on top of a desk.

7. A sketcher, having made a map on a supposed scale of 6 inches equal 1 mile, finds that his stride is 57 inches instead of 60 as he had supposed. How much does 6 inches on the map actually represent, and what is the true R. F.?

8. A map has a R. F. of 1/125,000. What would be its scale in yards per inch if the area of the map sheet were reduced to ¼ its present size?

9. Construct a graphic scale to read hundreds of yards, with an extension to read 10 yards, for a map having an R. F. of 1/5000.

10. On a map without scale the distance between two adjacent parallels of latitude is found to be 22⅓ inches. What is probably the scale of the map?

11. A troop of cavalry marching at a rate of 6 miles per hour and a company of infantry marching at a rate of 3 miles per hour, move at the same hour from *A* and *B* on *C*. Which arrives first, and in what time? (Select suitable points on 3″ map).

12. The distance between *A* and *B* on two maps, Nos. 1 and 2, are 15 and 20 inches, respectively. The scale of No. 1 is 167 yards to the inch. What is the scale of No. 2?

13. The scale of a French map is 2.5 centimeters equal 1 kilometer. Construct a scale to read hundreds of yards. Would you use a scale with an extension? Why?

14. A circular park on a certain map has an area of 225 sq. in. On another map the same park has an area of 9 sq. in. The R. F. of the first map is 1/2400. How many miles to the inch in the scale of the second map?

16. The scale of a certain map is 1 inch equals 167 yards. What are its R. F. and scale in inches per mile?

17. A map in the office of the Chief of Staff is used solely to calculate times of movement of troops from one part of the area to another. Its scale is 3 inches equal 1 mile. What would be an appropriate scale in connection with the movements of foot troops? Construct such a scale. Would a different scale be needed for truck trains whose average rate of travel is 10 miles per hour?

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SECOND LESSON.

The Rotundity of the Earth. Map Projections.

It will undoubtedly occur to the student that since the surface of the earth is spherical it cannot be accurately represented on a *plane* surface, such as a sheet of paper.

While this is true, yet just as our senses do not perceive the rotundity of the earth, so the error in depicting a small portion of it on a plane surface is too small to be of any importance to the military man, or to any other user of maps.

For all practical purposes the limited areas of the earth depicted on maps for tactical uses may be regarded as flat surfaces. This will be appreciated if we cut from the skin of an orange a very small piece. It can be compressed to a perfectly flat surface without noticeable distortion. When the vast size of the earth is considered it will be evident that the same is true of the very small portions of it represented on tactical military maps and sketches.

Accurate maps of large areas do indeed take into account the curvature of the earth, but with the making of these the line officer has nothing to do. The methods of depicting a spherical surface on a plane sheet of paper are known as "map projections," of which a number have been employed. When the entire earth is shown on a single sheet the distortion in the neighborhood of the poles becomes quite marked. But we do not conduct military operations with the aid of such maps.

As an introduction, however, to the subjects of direction and orientation, an understanding of the fundamental principles of geodesy will be helpful to the student.

Latitude and Longitude.

The earth being a globe, the positions of points on its surface are fixed by their *latitude* and *longitude*. The parallels of latitude are a series of imaginary circles passing around the earth, parallel to the equator. Manifestly they decrease in size as we go north or south from the equator, until they become mere points at the poles. The angular distance (measured at the center of the earth) from the equator to the pole is 90°. The latitude of any place is its angular distance north or south of the equator.

The meridians of the earth are imaginary great circles passing through both poles and perpendicular to the equator. The prime meridian passes through Greenwich, England. The angular distance, measured along the equator from the meridian of Greenwich to the meridian passing through any other place, is called the longitude of that place. The meridian of any place, since it runs from that place to the north pole is evidently the true north and south line at the place in question. Since all meridians meet at the poles they are evidently not parallel to each other. But within the limits of the area shown on any tactical map the convergence of the meridians is so slight as to be inappreciable, and they may be regarded as exactly parallel to each other and exactly perpendicular to the east and west lines, which may be regarded as parallels of latitude.

The meaning of the terms latitude and longitude, the convergence of the meridians, the distortion resulting from depicting the earth as a flat surface, etc., may best be understood by examining an ordinary school globe. This is a true map of the entire earth, depicted in the only way that accurately represents the relative positions of all points.

Direction. Azimuth and Bearing.

We are now prepared to consider another important element in both the reading and making of maps, which is *direction*.

The direction of the north pole, looking along the meridian of the place is called *true north*. The opposite direction towards the south pole, is south. Squarely to the right is east and to the left, west. The east and west line in any locality is the parallel of latitude at that locality, and for all practical purposes, within the limits of a military map, it is a line perpendicular to the meridian. These four directions are known as the *cardinal points*.

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It will be evident that the meridian and parallel at any point divide the observer's horizon into four quadrants or arcs of 90°.

These quadrants are known as, northeast, southeast, southwest, northwest. The *bearing* of a line running from the observer's position in any direction is expressed by giving the quadrant within which it lies, and the angle it makes with the meridian. Thus the bearing of the line *OB* (Plate 2) is N. 45° E., of *OA*, N. 60° W. Direction is also expressed by the term *azimuth*. Azimuth is measured in degrees, clockwise around the horizon, usually from the south point (sometimes from the north point). West is thus azimuth 90°; north, azimuth 180°; east, azimuth, 270°. The line *OB* has an azimuth of 225°, which is the same as bearing N. 45° E. The terms bearing and azimuth are thus convertible. The term "bearing" usually means "magnetic bearing."

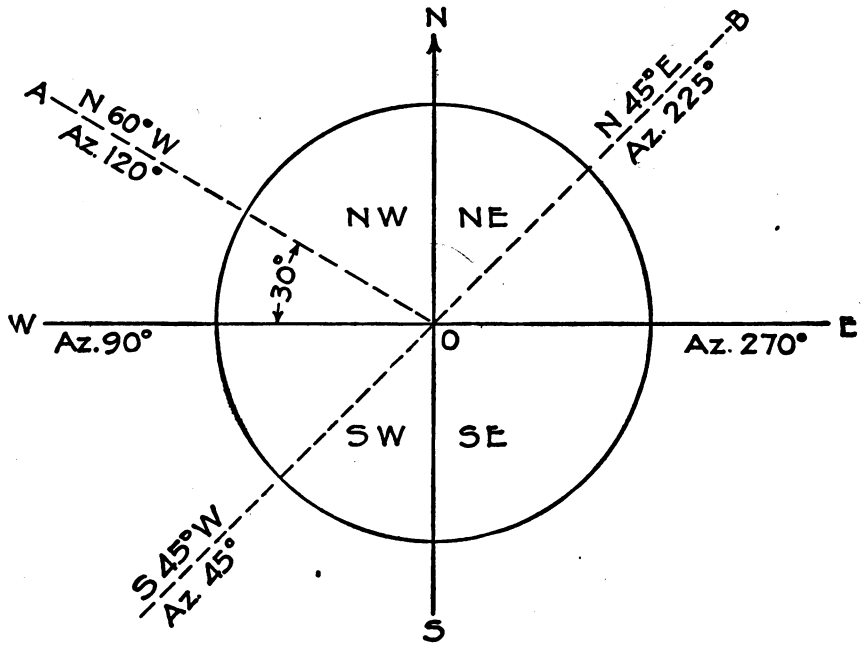

PLATE 2.—Azimuth and Bearing.

While civil practice generally employs the south point as the origin of azimuths most of the equipment of the army is graduated with the north point as the origin. The student is warned to note the practice in any particular case. Azimuths reckoned from the north point are readily changed to azimuths reckoned from the south point, or vice versa, by adding 180° to all azimuths less than 180, or subtracting 180 from all azimuths greater than 180. For example the azimuth 120° reckoned from the south point, would be 120 plus 180 equals 300° if reckoned from the north point. The azimuth 340 reckoned from the north point would be 340 minus 180 equals 160° if reckoned from the south point. In giving directions in tactical orders ambiguity may be avoided by using bearings, which have but one meaning.

Another method commonly employed in military operations for indicating direction approximately, is by means of an imaginary clock dial laid face up on the ground with the XII to the north. The observer is assumed to be standing in the center of the dial, and indicates direction by reference to the figures on the rim. By this system the direction of the line *OA* would be "ten o'clock."

The "*back azimuth*" or "*reverse bearing*" of a line, as *OB* (Plate 2) is the azimuth or bearing looking back from *B* to *O*. Thus the back azimuth of *OB* is 45° and its reverse bearing is S. 45° W. To change azimuth to back azimuth, add (or subtract) 180°. To change bearing to reverse bearing change both cardinal points of the forward bearing. The reverse bearing of N. 45° E. is S. 45° W.

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It will now be apparent that any point (A) on the ground (or on the map) may be located (horizontally) from another point (B) by the azimuth (or bearing) and distance from *B* to *A*. If, standing at *B*, we face in the indicated direction and walk in a straight line the indicated distance, we will arrive at *A*.

The Compass. Magnetic Declination.

Direction, on the terrain, may be determined in three ways: (1) With the *compass,* (2) from the sun, (3) from the stars.

The *compass* is a magnetic needle, mounted in a case or box, pivoted at its center, which by reason of the magnetic attraction of the earth, points always to a general locality known as the *magnetic north pole.* It is unfortunate that the magnetic north pole is not at the same place as the true north pole. But it is not. Also it does not remain in the same place, so that the compass at any place does not point in the same direction from year to year. Accordingly the compass needle does not lie parallel to the true meridian in most localities.

The angle between the needle and the true meridian is called the *magnetic* declination of the place. In certain localities the needle points true north, the declination being thus zero. The line joining these points is called the agonic line. In the United States it passes through Michigan and South Carolina. East of the agonic line the declination is west, increasing as we go east. West of this line the declination is east. The amount of this declination may be considerable. In the United States it varies from about 18° west in Maine, to 23° east, in the state of Washington. The lines joining points of equal magnetic declination are called *isogonic lines.* They are wavy or irregular lines.

The magnetic declination is subject to slight daily and annual variations. The needle is also subject to violent derangements from "local attractions," such as electric currents, local deposits of iron ore, steel structures such as bridges, railroads, automobiles, etc.

It is perhaps well at this point to note that in the graduations on the dial of a compass the quadrants are *sometimes reversed.* That is NE. appears on the *left* and NW. on the right instead of as in Plate 2. The SE. and SW. quadrants are similarly reversed. The purpose of this is to allow of reading the bearings direct. The compass needle cannot be pointed along the line whose bearing is desired. Accordingly the north and south line of the compass is laid parallel to the line, with north pointing in the desired direction, and the north end of the needle *on the reversed dial* then reads the magnetic bearing of the line. The best compasses for field use are provided with sights by which their north and south lines may be pointed in any desired direction.

From the foregoing it will be evident that the *true* bearing (or azimuth) of any line on the earth's surface, and its *magnetic* bearing (or azimuth) differ from each other by the amount of the magnetic declination. If the declination be *east,* the magnetic bearing of all lines in the NE. and SW. quadrants is less than their true bearing, and in the NW. and SE. quadrants greater than the true bearings. If the declination is west the reverse is the case. The student may prove this by drawing a figure in which the magnetic cardinal points and true cardinal points appear. As azimuth is measured continuously from 0° to 360° the magnetic azimuth is found by subtracting east declination from or adding west declination to the true azimuth. Thus if the declination is 16° east and the true azimuth is 9°, the magnetic azimuth is 360° plus 9° minus 16° equals 353°. (Azimuth is always positive, never negative, hence, minus 7° is expressed as 360°—7° equals 353° as in this case.)

The methods of determining direction on the terrain by the compass are described in more detail later under the subject of military sketching, as is also direction by the sun or stars.

Direction on the Map.

On most maps the meridian or true north and south line is indicated by an arrow pointing north. Usually, but not always, the right and left borders of the map are

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true north and south lines, the upper part of the map being north. Often also the magnetic meridian, or the direction in which the compass points, is indicated on the map by a half arrow, crossing the true meridian, and making with it an angle equal to the magnetic declination at the locality. The date of the map and the amount of the declination should always be shown.

Military sketches, as they are usually made with the aid of a compass, ordinarlly show the magnetic meridian only. An arrow, not marked, on such a sketch, may therefore be assumed to represent the *magnetic* meridian.

To draw on the map from a point *A*, a line having any given bearing or azimuth: Through *A* draw the true meridian (parallel to the edge of the map), and with a protractor lay off the given bearing from the meridian. To find the bearing or azimuth of a line joining two points *A* and *B*; through *A* draw a meridian and the line *AB*, and with a protractor measure the angle between the two lines.

Orientation and Determination of Position.

When a movement of troops is made by means of a map, as is usually the case, or when an individual is passing over or studying the terrain by the aid of a map thereof, it is necessary that the map be *oriented* and that the observer determine his own position on the map. A map is said to be oriented when *any* and *every* line on the map is parallel to the corresponding line on the ground. There are a number of solutions to this problem.

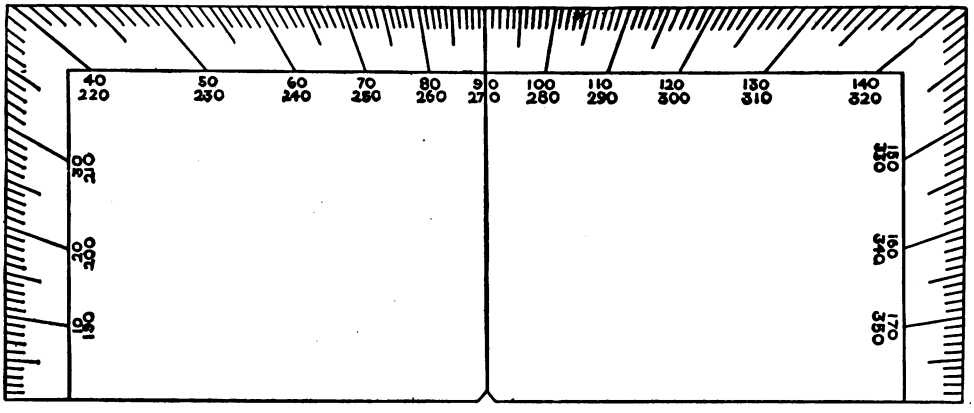

PLATE 3.—Protractor.

1st. *When the map exhibits a magnetic meridian.* Place the compass on the map with its north and south line (or the edge of the box) parallel to the magnetic meridian on the map. Rotate map and compass until the north end of the needle of the compass is at N. on the compass dial. The map is now oriented since its magnetic meridian is parallel to the compass needle. This method of orientation is independent of the position of the observer, that is, the observer's position need not be known.

2nd. *When the map exhibits a true meridian only.* If the magnetic declination is known or can be determined, place the compass as before with its north and south line parallel to the meridian. Rotate map and compass until the compass needle reads the magnetic declination, making sure that it is in the right direction (east or west).

3rd. *When the map exhibits no meridian or no compass is available.* If the observer can identify any line on the map and also on the terrain, he shifts the map until the map line (a road, for example), is parallel to the ground line. If no definite line is apparent the observer may often orient his map by noting prominent ground forms in the vicinity (both on the terrain and on the map), and shifting his

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map until the representations of these forms are in the same relative positions as the actual features on the ground.

4th. *When the observer's position is known and some prominent point can be identified on both map and terrain.* Lay the alidade along the line joining the observer's position with the visible point. Rotate the map until the point can be seen through the sights or along the edge of the alidade. The map is now oriented since the line from the observer to the prominent point on the map is parallel to the same line on the ground.

NOTE.—An alidade is a metal straight edge with vertical sights at each end, or a triangular ruler whose upper edge may be used for sighting. This method is the same as orientation by backsight, described in military sketching.

5th. *When the observer's position is unknown, and no meridian shown, or no compass available.* Select three prominent points which can be identified both on map and terrain. Lay a piece of translucent (tracing) paper on the board and stick a pin in it at any convenient point. Lay the edge of the alidade against the pin and sight in succession on the three points (on the ground), drawing lines in their direction from the pin. The map is not used in this operation. It is well to select the points so that the three lines drawn will intersect at angles not less than 30°. If the angles be sharper (less) than this the intersections are somewhat indefinite. Now lay the tracing paper over the map and "jockey" it about until the three lines pass through the proper points on the map. Prick through the common point of intersection. This will be the position of the observer on the map. To orient the map lay the alidade along any of the three lines and rotate the map until the corresponding prominent point is sighted along its edge (as in 4th case).

It will be noted that this method both orients the map and determines the observer's position thereon.

To determine the map position of the observer on an *oriented* map, select two prominent points on the ground and stick a pin in the map position of each. Lay the edge of the alidade in succession against each pin and rotate the alidade about the pin until the corresponding point on the ground is seen in prolongation of its edge. Draw the two direction lines on the map. Their intersection will be the observer's position on the map. If the observer is at some unknown point on a known road, it is sufficient to sight on a single distant point. The place where the resulting direction line crosses the road is evidently the map position of the observer. This procedure is known as *resection.*

For accurate orientation it is necessary to lay the map upon a table or leveled sketching board. For a very rough orientation, which will usually be sufficient for the identification of routes of travel or approximate location of position, it is sufficient to hold the map level in the hands. One experienced in reading maps will usually find no difficulty in orienting his map, at least approximately, and determining his position.

Polar Co-ordinates.

In the preceding pages we have noted that the horizontal position of one point *A* with reference to another, *B,* is fixed by the *direction* and *distance* of *B* from *A.* Every point on a map may thus be located from any assumed point, by measuring its direction (bearing or azimuth), and distance. The point from which measurements are made is known as the *origin* or *pole,* and the direction and distance are called the *polar co-ordinates* of the point whose horizontal position they fix.

Rectangular Co-ordinates. The Grid.

For practical purposes the location of a point by its polar co-ordinates is a rather slow process, and a more rapid system known as *rectangular co-ordinates* is accordingly preferred in military map reading.

Let us suppose we have a map of any piece of terrain, and that at some place on this map appear a meridian or north and south line, and a parallel, or east and west line. From the point of intersection of these lines lay off on each a number of

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points separated by some convenient distance, such as 1 mile, 1 kilometer or 1000 yards (to scale of the map). Through these points draw across the map a series of lines parallel and perpendicular to the meridian. They will divide the map into a number of squares known as a *grid,* as in Plate 4. As the meridians and parallels at different localities are not truly parallel, none of the lines of the grid (except the original meridian and parallel) will be true north and south or east and west lines. But for practical purposes, within the limits of any ordinary map they may be assumed to be such. With the angle between the grid lines and the true north and south and east and west lines the student need not here concern himself.

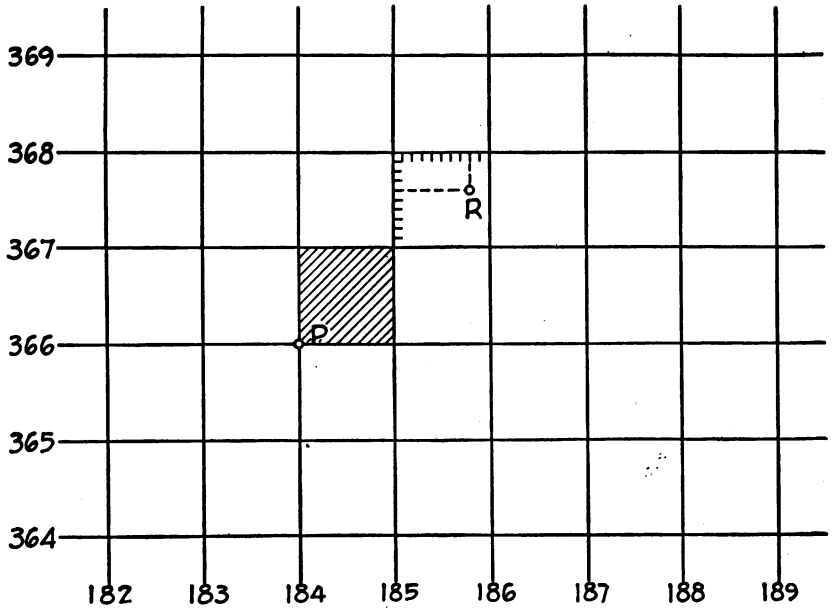

PLATE 4.—Rectangular Co-ordinates.

The north and south lines of the grid are numbered consecutively from left to right or from west to east, and the east and west lines from bottom to top or from south to north. The *origin* or zero point from which these lines are numbered is always located to the southwest of any point on any series of maps, so that all the grid line reference numbers are *positive* (plus).

Distances from west to east are called the *X* co-ordinates, and those from south to north the *Y* co-ordinates. Thus the *grid* or *rectangular co-ordinates* of the point *P* are 184-366. Since there is no danger of misunderstanding they may be written 184366, it being understood that the *X* co-ordinate is always written first, and that each co-ordinate contains the same number of figures. Since the significant figures 18 occur in all *X* co-ordinates and 36 in all *Y* co-ordinates *on this sheet,* the point *P* is sufficiently identified by the last significant figures of its co-ordinates as 4-6 or 46. This, of course, might not be the case on some other sheet.

The co-ordinates of the point *P* are also those of the square (cross-hatched) to the *northeast,* and any square is thus identified by the co-ordinates of its *southwest corner.* Thus the point *R* lies in the square 185-367, which may be written 185367 or simply 57. To locate the point *R* more accurately let us assume that the sides of the squares are further subdivided into 10 equal parts. Then it is seen that the point *R* is 8 subdivisions east and 6 subdivisions north of the southwest corner of the square in which it lies. Its co-ordinates may now be written 185.8-367.6, or 5.8-7.6, or, omitting the decimal point and dash, 5876. The sides of the squares may be further subdivided into 100 or even 1000 parts, and the point thus still more closely located. It being understood that as many significant figures (to the left of

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the decimal point) are given as necessary to identify the square and *no more,* it will be evident that no other point on this map could have the same co-ordinates. But in order to avoid any possibility of misunderstanding or loss of time, the decimal points and central dash may be shown.

If the squares of this map are 1000 yards on a side the co-ordinates 5.8-7.6 indicate that the point *R* is 800 yards east and 600 yards north of the southwest corner of the square 5-7.

It will be evident that the grid system is a much more rapid method of identifying a locality than the system of polar co-ordinates.

Because of their limited areas the grid system is not employed for rapid military sketches.

The parallels and meridians form a grid system in which any point is located by its latitude and longitude. These are called the *geographical* or *geodetic* co-ordinates of the point.

A very rough system of rectangular co-ordinates for the approximate location of points, is provided by dividing the edges of the map into a number of equal spaces, lettered on the east and west borders and numbered on the north and south borders. A point located as 6 *D* for example, would be one approximately opposite "6" on the upper (or lower) border of the map, and "D" on the right (or left) hand border.

According to our new standards the grids will be 1000 yd. squares for maps on a scale of 1 : 20,000, and 5000 yd. squares for maps on a scale of 1 : 62,500.

Notes.

The subject of geodesy, including the curvature of the earth, latitude and longitude, are best illustrated by means of a school globe. This is a matter of general information, but not vitally important to the line officer, either in reading maps or making sketches.

Direction, azimuth and bearing, are very important, and the student's grasp of these matters is best shown by his ability to solve practical problems. A compass should be exhibited and explained to the class. Exercises in orientation and location of position may be given with a map and compass in the classroom, but better, of course, on the terrain.

A large scale map showing the grid system should be exhibited, and the students required to solve problems in polar and rectangular co-ordinates until they fully understand the subject.

Practical Problems.

1. The true bearing of a line is N. 14° W. (a) What is its azimuth? (b) What are its back azimuth and reverse bearing?

Solution: (a) The azimuth of the north point is 180°. Hence, the azimuth of N. 14° W. is 180 − 14 equals 166°. (b) The back azimuth is the azimuth plus or minus 180°. Hence, 166° plus 180° equals 346°. The reverse bearing of N. 14° W. is S. 14° E.

2. In the above case the magnetic declination is 18° W. (a) What is the magnetic azimuth of the line? (b) What is its magnetic bearing?

Solution: (a) As the declination is west, the magnetic south point is *east* of the true south point, and all magnetic azimuths are *greater* than true azimuths by the amount of the declination. Hence, 166 plus 18 equals 184°, is the magnetic azimuth. (b) The true bearing of the magnetic meridian is N. 18° W. The line bears N. 14° W. Hence, it is 4° east of the magnetic meridian and its magnetic bearing is N. 4° E.

3. The true azimuth of a line is 98°. Its magnetic bearing is N. 88° W. What is the magnetic declination of the place?

Solution: The line is evidently in the NW. quadrant as its azimuth is between 90° and 180°. Its true bearing is 180°—98° equals 82° NW. or N. 82° W. Since its

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magnetic bearing is 6° greater than this the magnetic meridian is evidently 6° east of the true meridian and the declination is 6° east.

4. The bearing of a line is N. 45° W. What is its clock face bearing?

Solution: One o'clock is N. 30° E., 2 o'clock is N. 60° E. Hence, N. 45° W. is 1:30 o'clock.

5. A distant point has a true azimuth of 135° from the observer's position. When the sights of the compass are directed on this point the north end of the needle reads N. 32° W. on the compass dial. (a) What is the magnetic declination of the place? (b) Is this correct assuming that we are in the United States?

Solution: (a) The true bearing is evidently NW. and its amount is $180-135=45°$ or N. 45° W. The magnetic bearing is N. 32° W. Hence, the magnetic meridian is 13° *west* of the true meridian and the magnetic declination is 13° west. (b) This seems reasonable, as 13° W. is within the known limits of the magnetic declination in the United States.

6. The bearing of A from O is N. 60° W. and the distance is 300 yards. The bearing of B from O is N. 30° E. and the distance is 400 yards. What is the distance from A to B and the azimuth of the line AB?

Solution: The three points form a right angled triangle. The unknown side is $\sqrt{300^2+400^2}=\sqrt{250{,}000}=500$ yards. (Lay this out as a diagram.) The angle at B is one whose tangent is $\frac{3}{4}$. From the table of tangents this is about 37°. Hence, the azimuth of AB is 37° greater than that of OB. The azimuth of OB is $180+30=210°$. Hence, the azimuth of AB is $210+37=247°$.

7. The true bearing of a line is N. 15° W. The magnetic declination is 18° W. What is the magnetic bearing of the line?

Solution: The true bearing of the magnetic meridian is N. 18° W. The line is 3° *east* of this, hence, its magnetic bearing is N. 3° E.

8. A certain map extends from the equator to 30° N. latitude. What is the convergence of the meridians (*i. e.* convergence of two meridians one degree apart) in the limits of the map?

Solution: The convergence of the meridians will be the difference between the length of one degree on the equator and on the parallel of latitude, 30° N. The ratio of these two is as the cosines of their latitude, or as Cos 0° : Cos 30°. Cos 0° equals 1, and Cos 30° equals .87. One degree on the equator is 69 miles, hence, 1° at lat. 30° is $69\times.87$ equals 60 miles. Hence, the convergence is $69-60=9$ miles.

9. Assuming the above convergence to be uniform from latitude 0° to latitude 30°, what would it measure on a map on a scale of 1 inch equals 1 mile, 20 inches from bottom to top?

Solution: Assuming the circumference of the earth as 24,800 miles, 30° or 1/12 of this, would be approximately 2000 miles. In this distance the convergence is 9 miles or 9/2000 equals .0045 miles for each mile we move north. Our map covers 20 miles from south to north, hence, the convergence within its limits would be $.0045\times20$ equals .09 miles, or to the scale of the map, 9/100 or less than 1/10 of an inch.

10. The instructor should demonstrate the method of laying off a line having a given azimuth (or bearing), and of determining the bearing of a point A from another point B, by the use of the protractor. The students should then be required to make several such solutions. For this purpose the blackboard or a sheet of paper will answer, the map is not required.

11. If an ordinary school globe is available the instructor should point out the relations of parallels and meridians, the location of the poles, and the convergence of the meridians. He should then require the students to determine the latitude and longitude of certain large cities.

12. With a compass require the students to determine the magnetic bearing of points in the classroom.

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13. Determine the polar co-ordinates of a point A from another point B as an origin.

Solution: Through B draw a meridian. Draw the line AB. Measure the angle between these two lines with a protractor. Measure the distance AB with the assumed scale. From the measured angle calculate the bearing of the line BA. (This problem may be solved on a map, blackboard or sheet of paper.)

14. The polar co-ordinates of B from A as an origin are azimuth 225°, distance 800 yards. Locate B on the map or blackboard.

Solution: Draw a meridian through A. With a protractor lay off an angle of 225° from the south end of the meridian, in a clockwise direction, with the center of the protractor at A. On the final side of this angle lay off 800 yards with the known or assumed scale and mark the point thus determined B.

15. Construct a grid on the blackboard. Its sides are assumed as 1000 yards. Number the north and south lines from 180 to 190, and the east and west lines from 230 to 240.

16. The co-ordinates of a point, O, on this grid are given as 6.8—5.3. Locate the point.

Solution: The first co-ordinate is the X or east co-ordinate. Written complete it would read 186.8. Similarly the Y co-ordinate would read 235.3. The point is in the square east of the line 186 and north of the line 235. From the southeast corner of this square measure off 8/10 of the side of a square east on the east and west line, and 3/10 north on the north and south line. Erect perpendiculars to the grid lines at these points. Their intersection is the position of the point.

17. Assume a point, P, in any square of the grid, measure and write its rectangular co-ordinates.

Solution: Write the co-ordinates of the southwest corner of the square in which the point lies. Measure the distance of the point east and north of the southwest corner, in tenths of the side of a square. These will be the figures following the decimal point, thus:

Co-ordinates of southwest corner of square 182-238.

Complete co-ordinates of point P 182.7-238.4 or 2.7-8.4.

18. What is the distance between O and P in problems 16 and 17, calculated from their co-ordinates?

Solution: Draw through P a north and south line and through O an east and west line until they intersect. Draw the line OP. We now have a right angle triangle, in which the hypothenuse OP equals the square root of the sum of the squares of the other two sides. The length of the east and west side of the triangle is the difference between the X co-ordinates of O and P, and of the north and south side the difference between their Y co-ordinates, thus:

186.8—182.7 equals 4.1, length of east and west side.

238.4—235.3 equals 3.1, length of north and south side.

Remembering that the sides of the square are 1000 yards these distances are written as 4100 yards and 3100 yards. Then the distance between O and P is $\sqrt{4100^2+3100^2}$ equals 5140 yards.

Following the demonstrations of these problems by the instructor the students should be required to solve a number of similar problems.

The several cases of orientation and determination of position given in the lesson should be practiced both in the classroom, using assumed points, and on the campus, using a map of the college grounds. If the institution is in a city a large scale map may be obtained for this purpose. If the institution is in the country a Geological Survey map (R. F. 1/62,500) of the locality can probably be secured.

The following problems are similar to those of the same number whose solutions are given:

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1. The magnetic bearing of a line is S. 23° W. What are its magnetic azimuth and back azimuth?

2. The magnetic bearing of a line is S. 12° W. and the magnetic declination is 16° east. What are its true azimuth and back azimuth?

3. The true bearing of a line is S. 10° E. and its magnetic bearing is S. 3° W. What is the magnetic declination?

4. The clock face bearings of two lines are 2 o'clock and 7 o'clock. What are the azimuths of the lines and the angle between them?

5. A certain point has a true azimuth of 45° from the observer's position. When the compass sights are directed on the point the needle is found to read S. 38° E. What is the magnetic bearing? Can this be right? Why?

7. The true bearing of a line is S. 10° W. The magnetic declination is 16° east. What is the magnetic azimuth of the line?

8. What is the length of 1° of longitude at latitude 40°?

9. The north pole is shown at the center of a certain map. Its scale is 1 inch equals 1 mile. What is the divergence of the meridians at 16 inches from the pole? Which direction is south on this map?

THIRD LESSON.

Conventional Signs.

The many features, natural and artificial, which occur on the ground, are represented on the map by various symbols known as *conventional signs*. In order to read a map accurately and rapidly it is necessary that all officers be familiar with these signs.

Generally speaking these signs roughly resemble or at least convey a suggestion of the objects they represent. But they have not been thoroughly standardized and hence are different on maps by different governments and different agencies. The conventional signs to be employed by all bureaus of the U. S. Government have been standardized by the U. S. Geographic Board, and are published in a little pamphlet entitled, "Conventional Signs" issued by the War Department. They are used on nearly all government maps of fairly recent date (since about 1912).

In addition to the signs, many maps are printed in colors characteristic of features of various classes: For example, water in blue, vegetation in green, buildings, and railroads in black, contours in brown, important roads in red.

The more usual symbols, such as roads, railroads, buildings in general, woods, streams, contours, are the same or nearly the same on all maps, are soon learned and easily recognized by the student. The more unusual features are often described by short notes or their abbreviated names placed near them. This may be done on maps of large scale, and on small scale maps such unusual features would usually be omitted, or placed in the general class to which they belong, as in the case of buildings for various purposes.

Conventional signs are seldom drawn to any scale, even on large scale maps. Their appropriate size is determined by the scale of the map and the necessity for catching the eye of the reader. Thus, on a scale of 3" equal 1 mile, all roads, whatever their actual width, are shown as about 1/16-inch wide. On a scale of 6" equal 1 mile they are shown 1/10 of an inch wide. While this is far greater than the actual width of the roads on such scales, any lesser width would be difficult to draw and would not stand out clearly nor be readily identified.

As the scale of the map decreases the symbols become fewer and fewer in number and more and more conventionalized until, on a very small scale map, roads, railroads and streams are merely lines of different weights or colors, cities and towns mere circles or dots, and practically everything else disappears entirely.

The conventional signs for the various *routes of travel* or *communication* (roads, railroads, canals, telegraph lines, etc.) should be familiar to the map reader, as these features are always of great military importance, and usually shown on all military maps, even those of relatively small scale. On maps of water areas,

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wharves, docks, buoys and other aids to navigation, are shown by conventional signs.

The conventional signs employed for military sketches are much fewer in number and simpler in appearance than those which appear on printed maps. The sketcher has not time to make elaborate symbols. Also his symbols should not clutter his sketch and obscure important features. The more common features only are symbolized. Unusual features which are of military importance, may be indicated by notes on the sketch. The signs should conform to the standards as nearly as practicable.

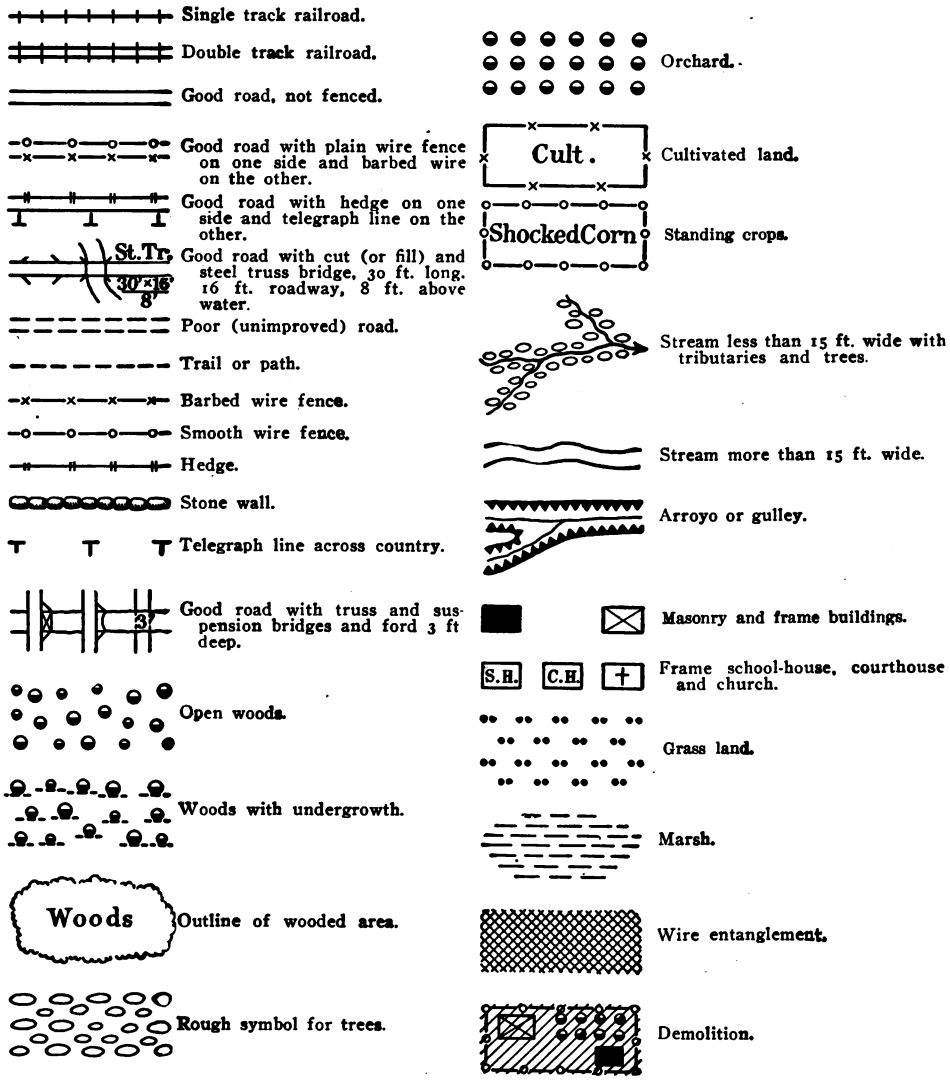

PLATE 5.—Conventional Signs Used in Military Sketching.

A number of the conventional signs commonly employed in military sketching are shown in Plate 5. They are drawn to about the size in which they would appear on a sketch to scale of 6″ equal 1 mile, the usual scale for position or area sketches.

The best way to study conventional signs is on the map. It is a good mental exercise to discover what the various symbols represent, and they are thus more strongly impressed on the mind than when seen in a pamphlet. Also in this manner the student will discover which are the signs most commonly employed, and with

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which he should therefore be especially familiar. In case of doubt consult the pamphlet or ask the instructor.

Contours are a form of conventional sign used to depict ground forms. They are sufficiently important to warrant special discussion later.

The features exhibited on a map are classed as *natural* and *artificial.* Artificial features are of course the work of man. They are sometimes called *cultural* features, but artificial seems a better term, inasmuch as cultural does not well describe houses, roads or railroads.

The military profession employs a great number of conventional signs which do not appear on ordinary maps. These include trenches, obstacles and other defenses, gun positions, troops of all kinds, depots and dumps, parks and repair shops, headquarters of various units, and a great variety of other military establishments. These symbols up to the present time have not been thoroughly standardized. They may be seen on maps used during the war.

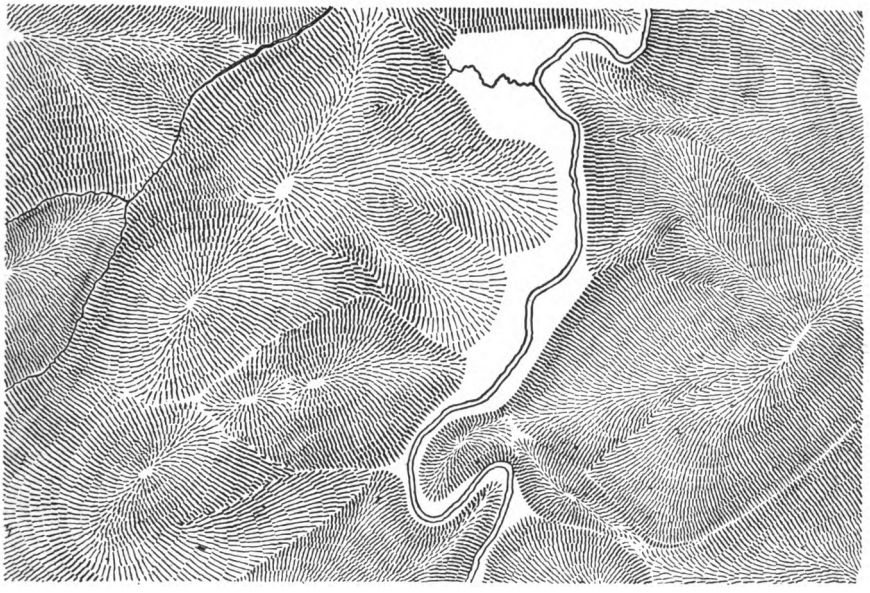

PLATE 6.—Hachures.

Military establishments are often shown by *overprinting* them *in colors* on the map. Our own works are indicated in *blue,* the enemy's works in *red.*

Elevation or Relief. Ground Forms.

We have thus far considered the various features represented on a map only in their horizontal relation to each other. But a map to be a complete description and picture of the ground must give information as to the heights or elevation of various points, and must depict ground forms as they exist in nature. This is accomplished by means of figures giving elevations, and by means of conventional signs known as *hachures,* hill and valley *shading* and *contours.*

Hachures and shading are commonly employed on foreign maps. They give only an approximate idea of the ground forms, and need not be further considered.

Contours.

A *contour* is an irregular curved line on a map (corresponding to an imaginary line on the ground) joining all points of any given elevation, or a line all points of which are at the same elevation. It is therefore a horizontal line.

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To gain a conception of what is meant by the term let us start at the seashore. The sea is a level or horizontal surface. Therefore the shore line is a contour because all points on it are at the same elevation—sea level. Now let us suppose that the level of the sea were raised, say 10 feet. The water would rush inland, passing into the valleys and up the slopes of the hills until it finally came to rest, creating a *new* shore line. This also would be a contour, as was the old shore line, and it would be at a *vertical interval* (V. I.) of 10 feet above the first shore line or contour. If we continued to raise the sea level 10 feet at a time, and to mark on the ground the successive shore lines thus produced, we should, on reaching the tops of the mountains, have the entire continent accurately contoured. A map on a plane sheet, showing these contours in their correct horizontal positions, with each contour numbered according to its height above the original sea level, would be a contoured or topographical map. From this map the ground forms could be reproduced in miniature, forming a *relief map,* the only kind of map which represents ground forms in their true shape.

Characteristics of contours. Let us now examine some of the characteristics of these curves called contours, as an aid both in map reading and map making. (See Plate 7.)

1. Every contour is a continuous closed curve. For a contour is the shore line of an imaginary sea, and we know that the shore line is continuous. If a man walked along the seashore and kept going he would eventually return to the same spot from which he had started. Of course the contour may not close within the limits of the map. In that case the two ends both pass off the map and meet somewhere beyond. A small closed contour indicates either a hill-top or a depression with no outlet. In the latter case there will often be water in it.

2. There may be any number of separate contours of the same elevation, but each will be a continuous closed curve. An island off the coast has a shore line, at the same elevation as, but entirely separate from the shore line of the continent. But the island shore line is a closed curve passing clear around the island. An island is a small continent, just as a continent is merely a large island.

3. Contours never touch or cross each other. For if they did we would have two different elevations for the same point, which is of course, impossible. There are two apparent exceptions to this rule, which are the case of a vertical and an overhanging cliff. In the former case the *map* contours are superimposed on top of each other. In the latter case the higher contours actually cross over and pass outside of all lower contours. It is to be remembered, of course, that the contours on the map are merely the *horizontal projections* of the imaginary contour lines on the ground. The latter never cross. However, to avoid the appearance of an impossible situation, cliff contours are not drawn on the map. The contours are drawn to the ends of the cliff until they have approached very close to each other, and the steep portion of the cliff is indicated by hachuring or shading.

4. Hill and valley contours go in pairs, or rather the same contour is encountered twice, once in going up the hill (or down the valley) and again, at the same level, in going down the hill (or up the valley) on the other side of the crest (or stream).

5. The spacing of the contours indicates the steepness of the slope of the ground. The closer together the contours, that is, the less the horizontal distance for the same rise, the steeper the slope. Uniformly spaced contours indicate a uniform slope. A *convex* hill or ridge is characterized by contours farther apart at the top and closer together at the bottom. For a *concave* slope the reverse is the case.

6. Valley contours are usually characterized by a *V* shape, the point of the *V* being at the place where the contour crosses the stream line at the bottom of the valley. Hill or ridge contours are usually characterized by a *U* shape, the point of the *U* being at the place where the contour crosses the watershed line of the hill or ridge. The points of the *V's* are *upstream* and those of the *U's* are *downhill.* Hills and valleys are thus usually distinguishable from each other by the characteristic shapes (*U* and *V* shaped) of their contours, even if the heights of the contours be not known. If there be any doubt the reference numbers should be consulted, and it

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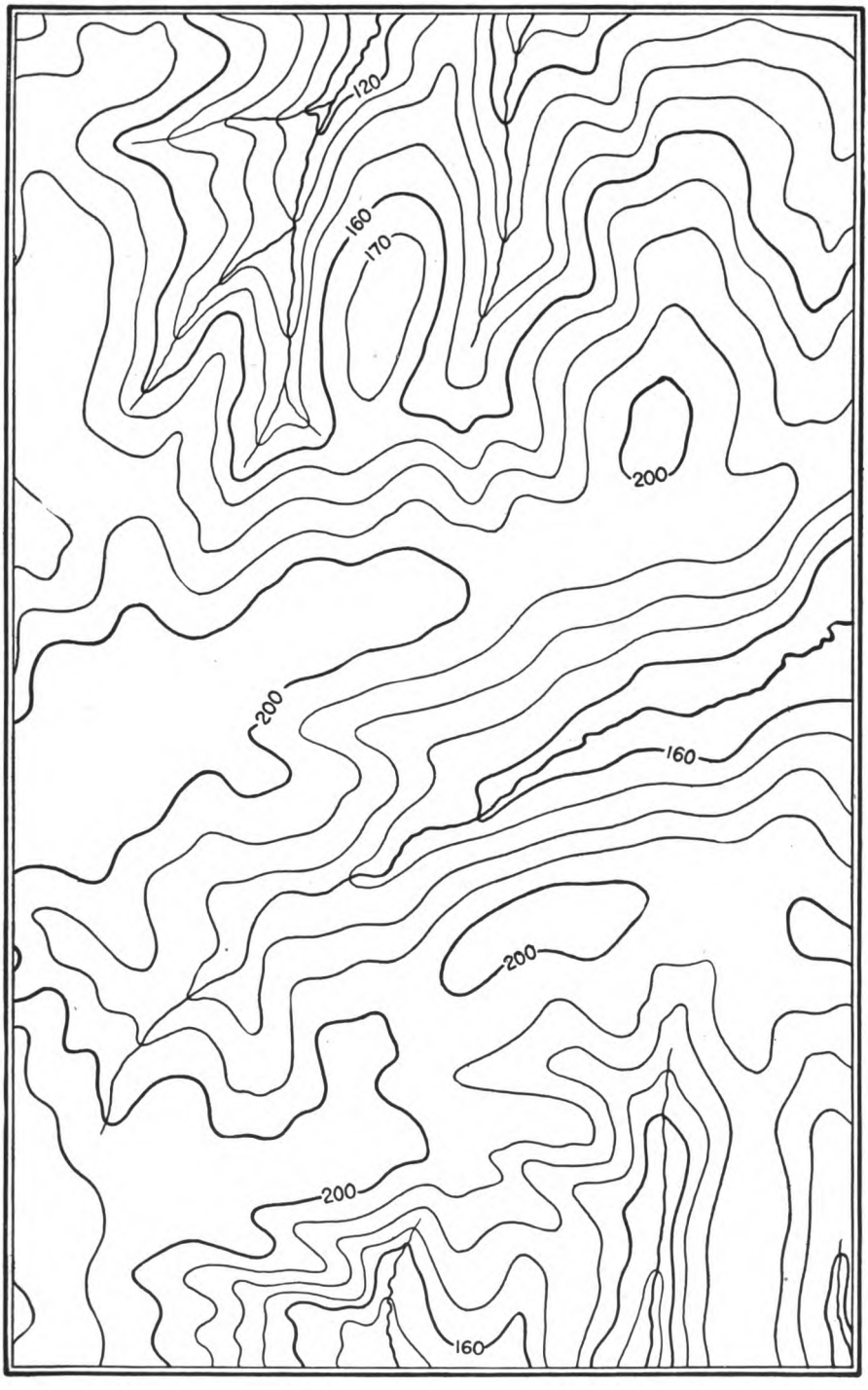

PLATE 7.—Characteristics of Contours.

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will be found that the higher contour lies *outside* the lower in the valleys and *inside* it on the hills.

7. Adjacent contours usually resemble each other, that is to say they are roughly parallel. Violent changes in the contour of the ground are unusual, but do occur in mountainous country. Changes in the form of the ground usually occur gradually, as indicated by adjacent contours bearing at least a rough resemblance to each other.

Other characteristics of contours are noted in the course in military sketching. It is of little use for the student to attempt to memorize the foregoing rules. The truth of them should be verified by study of the map, when they will be better impressed on his mind. Characteristic contours are shown in Plate 7.

Vertical Interval. Datum.

The *vertical interval* (V. I.) between adjacent contours is a constant on any one map. On American maps the V. I. is usually 5 feet or some multiple thereof. The vertical interval appropriate to any map is that which will properly portray the ground forms to the scale of the map. The larger the scale and the more diversified the terrain, the greater should be the vertical interval.

All elevations are measured above an assumed horizontal surface. Within the limits of any ordinary map, this may be considered a *plane* horizontal surface. It is known as the *datum* or *datum plane*. The exact position of the assumed datum is a matter of no great importance on any one map, inasmuch as it is the *relative* rather than the absolute heights which are important. For the sake of uniformity the assumed datum for most maps is *mean sea level*, which is an unvarying horizontal surface. In sketching it is *desirable* to use the same datum in order that sketches of different areas may be comparable with each other and with maps of the general locality. But if sea level is unknown a datum plane may be assumed. It should be below any point on the map or sketch in order that no contours may have a negative (minus) reference.

The *reference number* of a contour is its height above the assumed datum. Reference numbers should be written in gaps in the contours sufficiently often to enable their heights to be readily identified. Also as a further aid every fourth or fifth contour may be drawn in a heavier line. Thus, if the contour interval be 5 feet, the 20, 40, 60 and 80 foot contours may be made heavy. This convention is very commonly employed. Areas of different heights may be in different colors; for example, all areas of less than 100 feet elevation green, from 100 to 500 feet cream, from 500 to 1000 buff, from 1000 to 2000 dark buff, etc.

The heights of hill tops are frequently indicated by figures, which mean feet (elevations are always measured in feet). Hills are often identified by these figures, as "Hill 204."

A *watershed* or *divide* is a crest line on the two sides of which the rainfall flows away in opposite directions. On the American continent there are two great areas separated by a *continental divide*. All rivers which rise east of this divide empty into the Atlantic Ocean, and those which rise to the west empty into the Pacific. A watershed is the reverse of a stream. If the terrain should be turned upside down all streams would become watersheds.

Depth curves in water areas are submarine or subaqueous contours. They are for the benefit of navigators, and are usually measured *downward* from mean low water. The unit of measure may be feet or fathoms. A fathom is 6 feet.

Ground Slopes.

The *slope* of the ground at any point is the angle between the ground and the horizontal. Uniform slopes are rare in nature. It is seldom that a straight line between any two points will coincide with the ground throughout its length except on an artificial slope. When we speak of the slope of the ground between any two points it is to be understood that the *average* slope is meant. Road and railroad slopes are called *grades*.

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A slope may be expressed in *percentage,* or in *degrees,* or as a *gradient.* The per cent of slope is the number of feet of vertical rise (or fall) in a horizontal distance of 100 feet. Thus if *A* is 100 feet from *B* (horizontally) and 10 feet above it (vertically) the *average* slope from *B* to *A* is *plus* 10% (uphill) and from *A* to *B* *minus* 10% (downhill). The slope may also be expressed in degrees. Assuming the above case of a 10% slope, it will be apparent, from trigonometry, that 10/100 or 0.1 is the tangent of the angle of slope. The angle whose tangent is 0.1 is approximately 5° 45′, which is accordingly the *degree* of slope.

Very steep slopes, such as the sides of trenches, are expressed in *gradients,* or as a fraction in which the numerator is the vertical rise and the denominator the corresponding horizontal run, in any unit of measurement. Thus if the side of the trench rises 4 feet in a horizontal run of 1 foot the gradient is 4/1, expressed as "4 on 1."

A correct contoured map evidently conveys information by which the average ground slope between any two points may be obtained. Thus if the distance between *A* and *B* is 300 yards and their difference of elevation as shown by the contours is 45 feet, the slope, expressed as a gradient, is 45/300 × 3 equals 45/900 equals 1/20. Expressed as a per cent it is 5/100 or 5%, and the degree of slope (from the table of natural tangents) is approximately 2° 50′.

Slopes and grades are of great military importance as affecting the operations of troops in campaign. The practicability of various slopes for various movements should be known. The following table conveys some information of this kind.

Practicability of slopes and grades.

2 to	3%	Maximum for railroads.
	5%	Maximum for interurban electric lines.
5 to	6%	Maximum for main roads.
8 to	10%	Encountered on secondary roads. Practicable for all military transport. Difficult for cavalry to descend at a gallop.
	12%	Cavalry can descend at trot.
12 to	14%	Practicable limit for heavily loaded vehicles.
	16%	Practicable limit for field artillery, animal drawn.
	25%	Light vehicles can negotiate. Awkward for infantry to descend.
	35%	Practicable limit for pack transport.
	50%	Individual men or animals can ascend.
	100%	Infantry alone can negotiate with aid of hands.

The following table gives percentage in degrees and degrees in percentage for ordinary slopes:

1°	equals 1.75%	2%	equal 1° 10′
2°	equal 3.5%	4%	equal 2° 20′
3°	equal 5.25%	6%	equal 3° 25′
4°	equal 7%	8%	equal 4° 35′
5°	equal 8.75%	10%	equal 5° 40′
6°	equal 10.5%	12%	equal 6° 50′
7°	equal 12.25%	14%	equal 8°
8°	equal 14%	16%	equal 9° 10′
9°	equal 15.75%	18%	equal 10° 10′
10°	equal 17.5%	20%	equal 11° 20′
11°	equal 19.5%	22%	equal 12° 20′
12°	equal 21.25%	24%	equal 13° 30′
		100%	equal 45°

Per cent to nearest ¼, degrees to nearest 10′.

Notes.

A number of copies of the pamphlet "Conventional signs" should be available for consultation, but the students need not memorize these signs.

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The students should be practised in drawing, to proper scale, the signs used in sketching. They should be required to identify all the signs used on the Geological Survey and other maps, both with and without the aid of the pamphlets.

A number of maps showing conventional *military* signs, especially the French *plans directeurs* exhibiting friendly and hostile establishments *in color,* should be available for display.

The students should also be required, both with and without the aid of the pamphlet "Conventional signs," to interpret the various signs found on the Geological Survey and other available maps. This will give them a familiarity with the

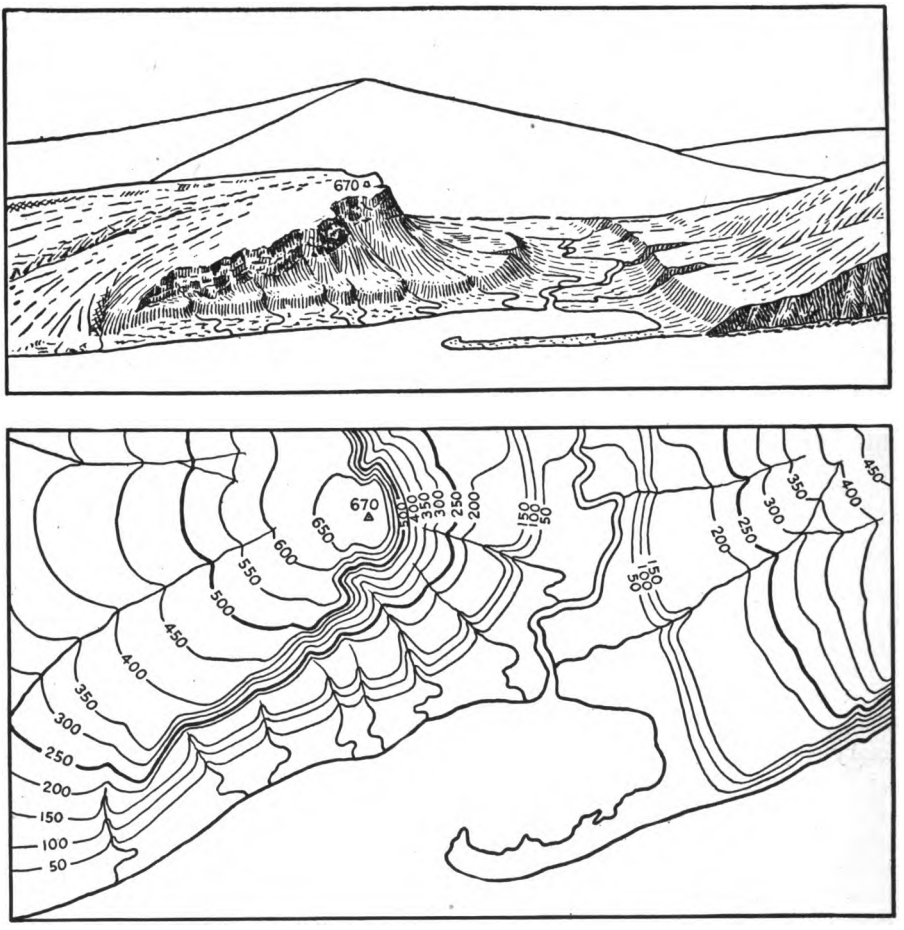

PLATE 8.—Ground Forms and Contours.

usual signs and will also impress on their minds the amount of detail exhibited by maps of various scales and of various classes. The instructor should examine the maps in advance and determine upon the points to be brought out. This is best accomplished by questions, of which the following are suggestions:

Which is the larger town, *A* or *B*?
Is the *X. Y.* railroad single or double tracked?
How many bridges and tunnels on this road between *A* and *B*?
Which is the best road from *A* to *B*? What kind of a road is it? Is it fenced?
Is there telegraphic communication between *A* and *B*?
Is there a railroad station at *A*? A freight yard?
Is there an interurban trolley line from *C* to *D*?

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Is the F—— Creek fordable? At what points?

How many bridges occur on the road from *G* to *H*? What kind of bridges are they?

What is the nature of the principal crops around *K*?

Is there underbrush in the woods near *L*?

The students should familiarize themselves with the conventional signs and explanatory notes ordinarily used in military sketching. They should then draw a sketch on a scale of 6″ equal 1 mile, of an imaginary terrain, employing these signs and notes (omitting contours).

Contours are the most mysterious thing about a map to the average uninformed person. Too much time can hardly be devoted to insuring that the students understand their nature and purpose, and their inherent simplicity and consistency. This knowledge is the very foundation of military map reading and sketching. Every means should be used to get the idea.

Each of the characteristics of contours mentioned in the text should be verified by the examination of a good contoured map, as well as by relief maps, the sand table, and on the ground.

Further study of the nature of contours is undertaken in the course in sketching.

If time is available the students may be required to construct a relief map, preferably in wax or cardboard, otherwise on the sand table or outdoors. It is desirable that the relief map be a *copy* of a contoured map (on the largest available scale), in order that the two may be compared.

The best method yet devised for instruction in contouring is that known as "logical contouring," or filling in the contours on a skeleton map on which the stream lines and critical points of the terrain are shown. This exercise is an indispensable preliminary to instruction in sketching, but if time be available a few *simple* problems in logical contouring may also be included in the course in map reading. Sheets for problems in logical contouring may be obtained from the Army Service Schools at Fort Leavenworth. (See Fifth Lesson.)

Practical Problems.

1. Each of the characteristics of contours explained in the lesson should be brought to the attention of the students, in the examination of a good contoured map, and by demonstration on the blackboard. They should then be practised in reading the ground forms from the contours, which may best be done by a series of questions, of which the following are suggestions:

Point out a range of hills, indicate the peaks and give their heights.

Trace the watershed along a ridge to its end.

Point out the passes, gaps or saddles in a range of hills.

Is the ground at *A* generally higher or lower than at *B*?

In which direction is the general slope of the terrain?

Point out a long valley.

Point out alternate spurs and ravines on a hillside.

Indicate the steepest slope in the vicinity of *B*.

Point out a uniform slope, a convex slope, a concave slope.

Indicate the ridges and valleys between *C* and *D*.

A camp is located at *E*. The enemy is to the east. Select a line of observation stations for an outpost.

Rain is falling at *F*. Trace its course to the stream into which it empties.

2. Draw a line on the map from *A* to *B*. (a) What is the average slope from *A* to *B*? (b) Is it plus or minus?

Solution: *A* and *B* are 800 yards apart and *A* is 75 feet higher than *B*. Hence, the slope is $75/800 \times 3$ equals $75/2400$, or in per cent, 3.1/100 of 3.1%. The slope is ***minus*** because we are going *downhill* from *A* to *B*.

3. Two points, *A* and *B*, are 600 feet apart and *A* is 46 feet higher than *B*. Express the slope from *B* to *A* as a gradient, in per cent and degrees.

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Solution: The gradient is 46/600 or 23/300. The same fraction with a denominator of 10° is 7-2/3/100 or 7.67%. From a table of natural tangents we find that the angle whose tangent is 7-2/3/100 or .0767 is 4° 23′ which is the slope in degrees.

4. Trace the line of a footpath from a point *A* to a point *B* with a grade not exceeding 8%. The contour interval is 10 feet.

Solution: Since the contour interval is 10 feet the length of the path between contours is 10/8 × 100 equals 125 feet. With the dividers opened to 125 feet on the scale of the map (or with a slip of paper) lay off a series of broken lines from one contour to another, starting at *A* and going in the general direction of *B*. (Plate 9.) Wind the path as necessary to reach *B*. If the first solution has too many turns, another path with fewer turns may be found. Note the two solutions shown. As this path is 125 feet long between contours 10 feet apart, its slope or grade is 10/125 equals 8/100, equals 8%.

5. (a) Express a slope of 9° in per cent. (b) Of 15% in degrees.

Solution: From the table in this lesson, 9° equal 15.75% . 15% in degrees is halfway between 14% and 16% (8° and 9° 10′) or 8° 35′ (approx.).

6. *A* and *B* are 750 yards apart and their difference of elevation is 150 feet. A road from *A* to *B* has a uniform grade of 4%. How long is it?

Solution: The length of a road on a uniform grade has nothing to do with the actual distance between *A* and *B*, but depends solely on their difference of elevation. Since it rises 4 feet in each 100 feet of distance, to rise 150 feet it must have a length of (150/4) × (100) equals 3750 feet.

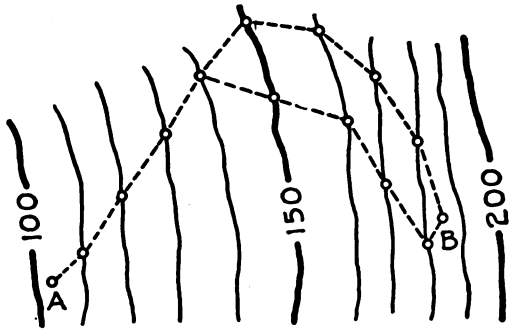

PLATE 9.—Locating a Foot-path.

7. A road from *A* to *B* has a uniform grade of 5%. The length of the road is 3 miles. What is the difference of elevation of *A* and *B*?

Solution: The length of the road in feet is 5280 × 3 equals 15,840 feet. 5% of this distance is 792, which is the difference of elevation of the two points.

8. A sketcher moving from *A* to *B* by road notes that the first 2 miles has an average up-grade of 5%. The next mile has a down-grade of 6%, and following this there is another up-grade of 2% for 3 miles to *B*. What is the difference of elevation of *A* and *B* and which is the higher point?

Solution: In the first 2 miles, or 10,560 feet, the road has an up-grade of 5%, hence, it rises 528 feet. In the next mile, or 5280 feet it falls 6% of 5280 or 317 feet. In the next 3 miles it again rises 2% of 3 miles, or 15,840 feet, which is 317 feet. The last two counterbalance each other, one being up and the other down. Hence, the total rise is 528 feet and *B* is that much above *A*.

9. Rain is falling at the point *A*. Trace its course to the stream (shown on the map) which it ultimately enters.

Solution: The water will run straight down hill on the line of steepest slope, perpendicular to the contours, until it reaches a drainage line (small stream or drainage line of a valley). It then follows the drainage lines to a small stream, and the small stream to the larger one into which it flows.

10. A camp is located at *A*. The enemy is known to be to the east. Select the best observation stations for the outpost of the camp.

Solution: They will be found on the crests of the ridges and tops of hills east of the camp (and extending well north and south) and at least a mile beyond it.

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11. An entire practical period may be well devoted to an exercise in logical contouring—filling in the contours on a sheet showing the drainage lines and heights of critical points. The instructor should first demonstrate the procedure, and then require each student to solve a very simple problem in contouring. More exercises in logical contouring should be given in the course in sketching.

12. A convoy of heavily loaded wagons is ordered to march from *A* to *B*. Select the best route for the movement.

Solution: The main roads, which are readily distinguishable on the map, are the best routes. For heavily loaded wagons it is desirable that the maximum grade should not exceed 10%, and there should be no *long* up-grades steeper than 6 to 7%. First examine the shortest main route from *A* to *B*. It will probably answer. But if its grades are not satisfactory, investigate the next shortest main route.

The following problems are similar to those of the same number whose solutions are given:

2. *A* and *B* are 1000 yards apart and *A* is 60 feet higher than *B*. But halfway between *A* and *B* is a stream which is 50 feet lower than *B*, the ground sloping almost uniformly up from the stream. What is the average slope from *A* to *B*? What would be the grades of a footpath running straight from *A* to *B*?

3. Two points, *A* and *B* are 2 miles apart, and *A* is 675 feet higher than *B*. Express the average slope between the two points as a gradient, in degrees and in per cent, and give it its correct algebraic sign (plus or minus), assuming that we are looking from *A* to *B*.

4. Select two points on opposite slopes of the same valley, and cause the students to trace a footpath going down the hill from *A* and up to *B*, the footpath to have a maximum grade of 8%, and to be the shortest and straightest possible.

5. Convert $1\frac{1}{2}°$, 9° 30′, 13° into per cent, and 3%, 5%, 7%, 9% into degrees. Use first the table in the text (by interpolation). Afterwards verify the results from a table of natural tangents.

6. *A* is 800 feet higher than *B*. On the road between them there is one point which is 500 feet below *B*. The road has a uniform grade of 5% (both up and down hill). How far is it from *A* to *B* by road?

7. A road from *A* to *B* has a uniform up-grade of 8%, except for a quarter of its length, which has a down-grade of 6%. The road is $4\frac{1}{2}$ miles long. What is the difference of elevation of *A* and *B*?

8. A sketcher from *A* to *B* by road notes the following data:

Elevation of *A* 872 feet.
Road from *A* to *B*:
1st mile, up-grade, 6%.
Next $1\frac{1}{2}$ miles, up-grade, 4%.
Next 4 miles, down-grade, 5%.
Next mile, up-grade, 7%.

What is the elevation of *B*?

10. Select the general position of an outpost observation line for a camp at *A*, the enemy being in the east.

12. A battalion of field artillery wishes to move across country from *A* to *B*, but cannot readily negotiate a slope of more than 16%. Can they move in a straight line from *A* to *B*? If not, what is their shortest route?

FOURTH LESSON.

Relief Maps.

The best conception of the nature of ground forms and of the characteristics of contours is afforded by what is known as a *relief map*. This is a model, in wax, sand, clay, plaster, or papier maché, of the ground as it actually exists. In order to bring out the ground forms more clearly it is usual to *exaggerate* the vertical scale, that is to make it relatively larger than the horizontal scale in the proportion, for example, of 5 to 1 or 10 to 1. This causes the miniature hills of the relief map to

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appear higher, its slopes steeper and its valleys deeper than those of the terrain it represents. If now the contours be traced on this map a very graphic representation results. The characteristics of contours, and the reasons therefor, are made perfectly clear.

The construction of a relief map is an interesting and instructive process. A copy of a small section of some large scale map may be made by the students if time is available, for example 1 sq. mile of a map on a scale of 12 inches equal 1 mile. The procedure is as follows: Determine upon the vertical interval between contours *to be employed for the relief map.* This should be *exaggerated.* Suppose it to be ¼ inch. Construct a form 12 inches square whose sides are ¼-inch high. Lay the form on the table, fill with wax, and level off. Trace on the wax the lowest contour appearing on the map, and remove all wax *below* the level of that contour. Do likewise for the next highest contour, and superimpose in its proper position on the first. Continue the process until the last (highest) contour is placed.

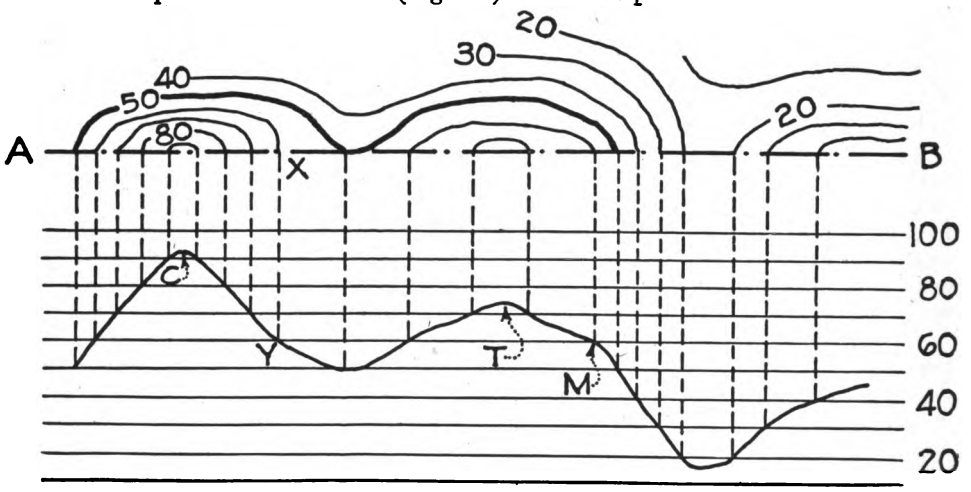

PLATE 10.—Construction of a Profile.

We now have a correct relief map except that the ground rises from one level to another by a series of vertical steps instead of continuous slopes. The angles of the steps may be filled in with wax and smoothed off with a tool. Other topographical features may be traced on the wax with a pencil point, or represented by bits of paper.

Relief maps have been used to a limited extent only heretofore, because of the time and cost of making them and the difficulty of moving them about. Methods for the cheap and rapid construction of relief maps in papier maché have been developed. Such maps are easily carried about, and it is certain that in the next great war they will be extensively used, as their value for tactical purposes is very great.

If wax be not available a relief map may be made of layers of cardboard of uniform thickness in the manner described. The contours are transferred to the cardboard from the map by means of carbon sheets.

The sand table is the form of relief map most commonly employed in the instruction of the R. O. T. C. Its preparation is described in detail at the beginning of the course in Minor Tactics.

Profiles.

A *profile* or cross-section is a line cut from the ground surface or from an imaginary relief map, by a vertical plane. A profile along any line may be constructed from a contoured map. As in the case of relief maps the vertical scale of a profile is usually exaggerated, that is, made relatively greater than the horizontal. The vertical scale should not be a mere multiple of the horizontal scale, but one convenient for use. For example, horizontal scale 12 in. = 1 mile, vertical scale 1 in. = 50 feet.

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Let *AB* (Plate 10) represent any line on a map, cutting the contours as shown. To construct a profile cut from the terrain by a vertical plane through *AB*, we proceed as follows: On a sheet of paper rule a series of equidistant parallel lines, the distance between which is the *V. I.* of the map to the exaggerated scale selected for the profile. Number these lines with the contour heights, beginning with the lowest contour cut by the line *AB* and ending with the highest. In this case the *V. I.* is

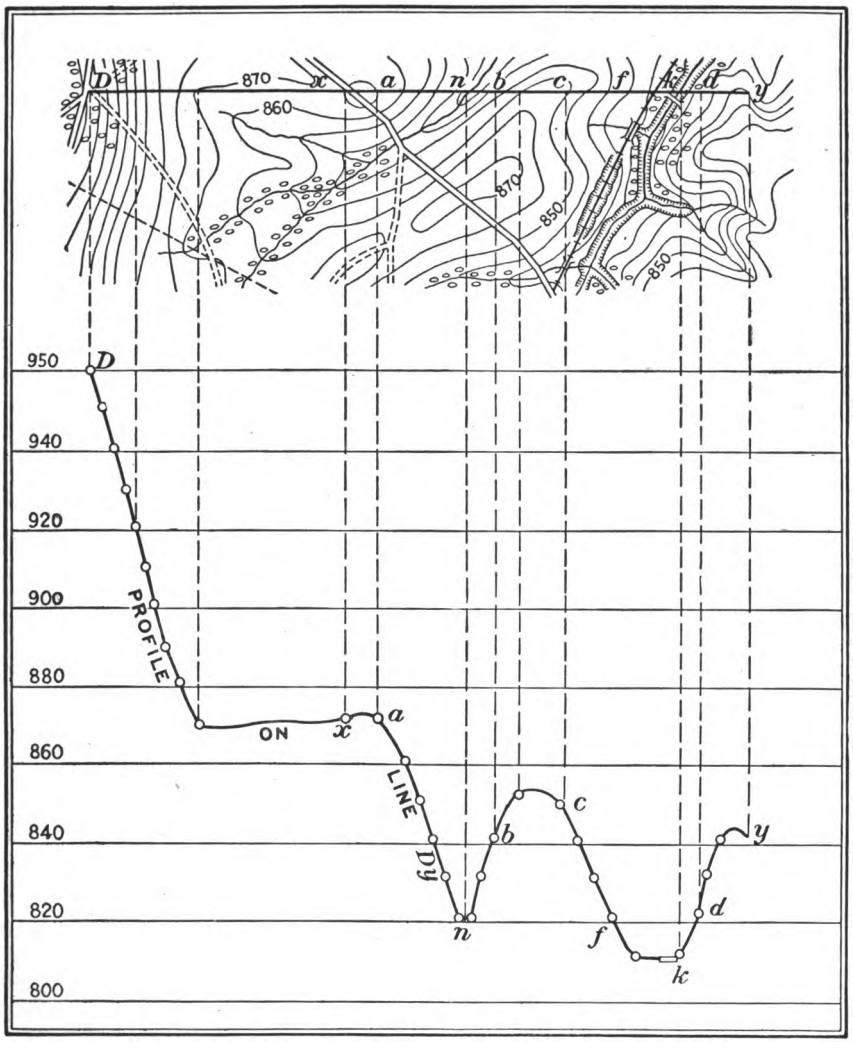

PLATE 11.—Construction of a Profile.

10 feet. Lay the edge of the sheet along *AB* (on the map) with the ruled lines parallel thereto. From each point where a contour crosses *AB* drop a perpendicular (as XY) to the ruled line having the same reference number, and mark the point of intersection (Y). A curved line joining the points thus located will be the profile on *AB* with the assumed vertical exaggeration. (See also Plate 11.)

Topographical and military crests. The *topographical* or *geographical crest* of a ridge is a line joining its highest points. The *military crest* is that position from which the forward slopes may be seen, or the highest position from which a line of riflemen could cover the forward slope with their fire. At *C*, in the profile

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(Plate 10) the topographical and military crests are practically coincident. On the next ridge to the right the topographical crest is at *T* and the military crest at *M*.

Profiles are used in engineering for the calculation of quantities of earth excavation, and for other purposes. They are also used for the solution of visibility problems, that is the determination of whether a certain area or a certain point is visible from another point.

Visibility of Points and Areas.

Problems in visibility frequently arise in military operations. Suppose it be desired to ascertain whether a point *B* is visible from a point *A*. Construct a profile, as heretofore explained, between *A* and *B* (Plate 12). Draw a straight line from *A* to *B*. If it does not strike the ground at some point between *A* and *B* the latter are mutually visible, each from the other. If there be trees growing on the ridge *H* between *A* and *B*, allowance must be made for their height (Plate 12). Various other visibility problems are readily solved by the use of profiles.

For example: *P* is not visible from the ground at *A*. How high an observation tower is required at *A* to see *P*? Draw a vertical line *AS* above *A*. From *P* draw a straight line just clearing the ridge *H*. It intersects *AS* at *R*. Then *AR, measured with the vertical scale of the profile,* is the height of tower required for the observer to see *P*. Where should artillery be placed to be concealed from an observer in the tower *AR*? Answer: Anywhere between *H* and *P*.

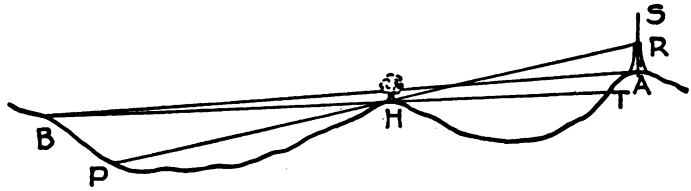

PLATE 12.—Visibility of Points.

An experienced map reader can solve many visibility problems without actually constructing a profile, or rather by a *mental* profile. Thus in the case shown in Fig. 12, is *A* visible from *B*? The observer, by reference to his contoured map, perceives that all the ground between *A* and *B* is lower than either of the points, except the ridge *H*. Therefore, it is simply a question of whether or not *H* cuts off the view. The observer notes that *H* is $\frac{3}{5}$ of the distance from *B* to *A*, and that *A* is 60 feet above *B*. Hence, at *H* the line of sight from *B* to *A* will be $\frac{3}{5} \times 60 = 36$ feet above *B*. The map shows that *H* is only 25 feet higher than *B*. Therefore, it is below the line of sight from *B* to *A* and does not interfere with the view. Another method would be as follows: Measure the distance *BH* on the map. It is found to be 9000 feet. *H* is 25 feet above *B*. The slope of the line of sight from *B* to *H* is hence, 25/9000 or 1/360. *A* is 15,000 feet from *B* and 60 feet above it. Hence, the slope of the line of sight from *B* to *A* is 60/15,000 or 1/250. The latter slope is *steeper* than the former, hence, the line of sight from *B* to *A* passes above *H*, and *A* is therefore visible from *B*.

Visibility problems may be rapidly solved by the use of a graduated rubber band. Suppose the lowest contour in the locality under consideration to be 360 feet and the highest 530 feet. Graduate the band from 36 to 53, each graduation representing a horizontal interval corresponding to 10 feet of vertical height. Suppose it be desired to ascertain whether a point *A*, elevation 390, is visible from a point *B*, elevation 510, over intervening ridges. Stretch the band so that the graduation 39 falls at *A* and the graduation 51 at *B*. The edge of the band now represents the line of sight from *A* to *B*. The height of the line of sight at *A* is 390 feet, represented by the 39 graduation on the band. Its height at *B* is 510 feet, represented by the the 51 graduation. As the line of sight is a straight line rising uniformly from *A* to

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B, it will be evident that any intermediate graduation on the band (multiplied by 10) will be the height of the line of sight at that point. Note the contours cut by the edge of the band. They represent the height of the ground along the line of sight. If any one (or more) of these contours has a reference number greater than 10 times the reading on the band at the point where it cuts the contour in question, then the ground at that point (as shown by the contour) is above the line of sight (as shown by the edge of the band), and *B* cannot be seen from *A*. If the band readings (multiplied by 10) are greater than those of any contour, at the point of intersection of the contour and the edge of the band, then the line of sight is everywhere above the ground, and *B* and *A* are each visible from the other. The band should be of red rubber graduated in black ink.

To determine the *areas* visible to the front from a point *A* on the map: Draw a series of straight lines radiating from *A*. Construct on each a profile. On each profile determine the points separating visible from invisible areas (Plate 13). Join the points thus

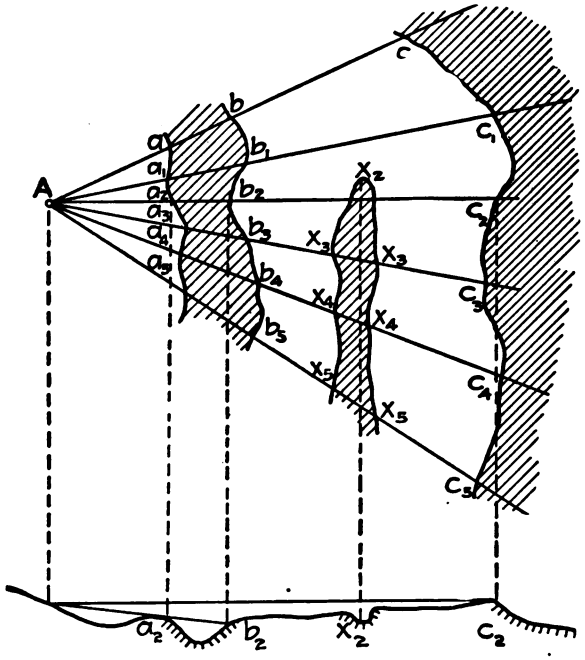

PLATE 13.—Visibility of Areas.

determined, by continuous lines. These lines are the boundaries of the visible and invisible areas. The latter should then be cross-hatched or tinted in color. In constructing these profiles for the solution of visibility problems it is not necessary to complete the profile. The crests and hilltops are the critical points. The valleys, or at least the bottoms thereof, are usually either certainly visible or certainly invisible. Thus in Plate 12, it will be evident at once that the valley between *B* and *H* is visible, and that between *H* and *A* invisible, to an observer at *B*. The rubber band may also be used to aid in the solution of these problems. Thus in Plate 12, having placed the crest *H* on the profile, stretch the rubber band along the corresponding line on the map, with the proper readings at *B* and *H*. Now note the point (*T*) on the hillside below *A*, where a contour has the same reading as the band. After a little practice the entire problem may be solved by the use of the rubber band alone. (Plate 14).

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Visibility by Relief Maps.

A relief map permits of the graphical or direct solution of visibility problems. Suppose it be desired to determine the visibility from a point *A*. Attach one end of a thread at *A* by a pin or tack. Stretch the thread taut to any other point *B*. If the taut thread clears the intervening terrain at all points, *B* is visible from *A*. If not, the ridge which interferes with view is at once evident. The solution of the problem of area visibility is particularly easy and interesting on a relief map. Place a miniature electric light at *A*. All areas visible from *A* will be illuminated, all invisible areas will be in the shade. If there is an observation tower at *A*, raise the light vertically to the proper height of the tower, on the vertical scale of the relief map. The areas visible from an aeroplane or observation balloon in any locality and at any height, are as readily determined by the use of the miniature light.

These visible and invisible areas may be permanently recorded on an ordinary map as follows: With the light in position at *A*, photograph the relief map from above, to the scale of the map on which the visibility from *A* is to be recorded. The visible areas will appear in white, the invisible areas in black on the photographic print. They are easily transferred to a map.

The points and areas visible and invisible both from our own and the enemy's observation posts are of great military importance in determining the probable localities in which troops and establishments of various kinds are or may be concealed, and the points from which such localities may be seen.

Aerial Photography.

Aerial photography, an outgrowth of the World War, affords a most rapid means of gathering information for filling in maps. It is the most important agency by which the establishments and activities of the enemy are detected.

The ability to read an aeroplane photograph, that is, to discover all the information it really contains, requires considerable training and practice. The average line officer will not be called upon for expert work of this class. It is sufficient that he be familiar with the general nature and use of aeroplane photographs, and the more familiar features, such as trenches and obstacles, which appear thereon.

The complete study of aeroplane photographs includes *interpretation, restitution* and *exploitation*. Interpretation consists in recognizing the various works of the enemy which appear on the photos. Restitution consists in the correct representation of obscure details and their accurate location and portrayal on a map. Exploitation consists in divining or discovering the plans of the enemy from the information revealed by the photographs, and using the information to our own advantage. This latter is a tactical and strategical study.

During a battle, aeroplane photographs assist in following its progress, determining the effect of our own artillery fire, etc.

Up to the present time no satisfactory method for determining relative elevations or the contour of ground forms from aeroplane photographs has been developed. Such photographs furnish certain information as to relief or elevation, but not sufficient for the construction of an accurate contoured map.

Map Reproduction.

During war time maps are reproduced in large quantities for the use of the military forces. As many as possible are printed or lithographed in large, well-equipped plants established for the purpose.

In the field, near the front, maps are reproduced by field lithography, the hectograph, and blue printing. The two former methods permit reproduction in colors. For nearly all military sketches of small areas, of which only a limited number of copies is required, the usual method of reproduction is by blue printing. In order that they may be blue printed, sketches should always be made on *translucent* or *tracing* paper. If a sketch has been made on opaque paper it may be retraced, or the paper may be made translucent with oil, banana oil being best for this purpose.

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Data which Should Appear on a Complete Map.

It is well at this point to summarize the features that should appear on and the information that should be conveyed by a good map for military purposes. In general this should be *all the information of military value appropriate to the scale of the map*. But in order to avoid burdening any one map with too much detail, very special information, such as geological data, is usually displayed on maps *compiled* (but not specially surveyed) for that purpose. A topographical military map should exhibit information of *tactical* and *strategical* value as distinguished from the technical information usually conveyed by special maps.

Every topographical map for military use should display the following general information:

1. Dates of survey and latest corrections or additions.
2. Name of the bureau or department, and usually also the names of individuals who are responsible for the accuracy and completeness of the map.
3. Methods employed in the survey, both for control and detail, as indicating the accuracy of the map. Sometimes the degree of accuracy, or "probable error," is stated.
4. Usual names of all the localities represented.
5. The representative fraction of the map, and a graphical reading scale.
6. The datum plane and vertical or contour interval.
7. The true and magnetic meridians and the amount of the magnetic declination.
8. The limiting latitudes and longitudes of the area covered by the map.
9. A grid system to permit rapid location of points.
10. If the map is one of a series covering a larger area this fact should be noted on the map.
11. Name of the printing plant in which the map was produced, and of the bureau from which additional copies may be obtained.
12. Signature and title of responsible officer who authorized the publication of the map—except when it is issued by one of the well-known mapping bureaus.

Notes.

Each student should be required to construct at least one profile. Cross-section paper, if available, is useful in constructing profiles. The vertical scale should always be greatly exaggerated.

Visibility problems are useful as map reading exercises, and every student should be required to solve a number of them during the periods devoted to "practical" work. These should be continued until the student can solve simple visibility problems *without constructing a profile*. A great number and variety of problems may be laid on any contoured map. The rubber bands used for visibility problems should be of *red* rubber graduated in *black* ink.

Aerial photography has reached the stage of development where only the specialist can be familiar with all its refinements; but every line officer should have a general knowledge of its purpose and sufficient training to read aerial photographs in order to supplement personal reconnaissance of the ground, which modern warfare now renders so difficult.

The process of making blue-prints should be thoroughly explained, and if possible, the students should be taken to a laboratory to see blue prints actually made.

The data which should appear on a good map (referred to at the end of the lesson) is of great importance. The students may well be required to memorize the items listed. They should be required to criticise existing maps on which important information is lacking.

Practical Problems.

1. Having demonstrated the construction of a profile, the instructor should require each student to construct one, using a greatly exaggerated vertical scale. Visibility problems on the line of the profile should then be solved with its aid.

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2. Can a lookout at the point *A* see an enemy at *B?*

Solution: This is the typical visibility problem. First draw the line *AB*. Construct a profile on this line. On the profile draw a straight line from *A* to *B*. If it does not touch the ground except at *A* and *B* the answer is yes. Five feet may be allowed for the height of the observer's eye above the ground. Lay off the 5 feet to the *vertical scale of the profile*. Make allowance for trees.

For a more rapid solution, look along the line *AB* on the map and mark the various spurs and crests which *might* interrupt the view. Stretch the graduated band from *A* to *B* so that it reads the height at each point, then note the reading on the band and on the contours at each spur or crest. If at any of these the contour reading is *greater* than the band reading, the spur interferes with the view.

If no rubber band is available: Suppose the elevation of *A* to be 830 feet and that of *B* 890. The difference is 60 feet. On a strip of paper mark *A* and *B* at the proper distance. Divide the strip in half by folding it, and then by eye or by rough measurement divide each half into 3 parts. Mark these divisions 830, 840, up to 890. The strip of paper may now be used as was the rubber band. Or to divide any distance, as *AB* into any number of equal parts: On a long sheet of paper rule a number of equidistant parallel lines. Number them from 0 up. To divide *AB* into 6 parts, lay the strip over the ruled lines and shift it until *A* is on the line marked 0, and *B* on the line marked 6. Then mark the point where the edge of the paper cuts each ruled line.

3. What portions of the road *AB* are visible to a lookout at *C?*

Solution: By an examination of the road determine the portions which are manifestly visible, and those which are manifestly invisible. Mark an *approximate* point *P*, where the road first comes into view from *C*. From *C* draw two lines, one on either side of *P*. Test these for visibility by profile, rubber band, or strip of paper as in the last example. If one shows the road visible and the other invisible the point where it comes into view is evidently between the two lines. This may be sufficiently close. If not draw a third line from *C*, between the other two and test for visibility. Suppose the road to be invisible on both lines. On line 1 on the right, the line of sight is 8 feet above the road. On line 2, on the left, it is 3 feet above the road. Then the point where line 2 crosses the road is approximately $\frac{5}{8}$ of the distance from the point where line 1 crosses, to the point where the road comes into view. The point of first visibility is determined with sufficient accuracy in this manner, especially when it is remembered that the heads of persons moving on the road will come into view some time before the road itself is visible. This problem is of importance in determining what portions of a road must be screened from hostile observation.

4. What areas, to the front are visible from a 40 foot observation tower at *A?*

Solution: Draw a number of lines radiating to the front from *A*. By means of profiles or rubber band determine the visible and invisible areas along each line. Draw the lines connecting the points of division, as in Plate 13. To determine the area concealed from view by a spur, draw lines on the map tangent to the contours at the top and bottom of the spur, and at each sharp change of slope, and with a rubber band or graduated strip of paper find the points where these lines of sight pierce the ground beyond the spur. Thus suppose the elevation of *A* (Plate 14) to be 570 feet and the elevation of a contour to which a tangent is drawn from *A* to be 520 feet. Stretch the rubber band until 57 is at *A* and 52 at the point of tangency (*B*), and look for the point beyond where a contour reading coincides with a reading on the band (470). This is a point on the boundary line between the visible and invisible areas.

5. The average slope between *A* and *B* is 4%. An electric railroad, with a uniform grade of 4% runs on a straight line (tangent) from *A* to *B*. What is the depth of the deepest cut, and the height of the highest trestle on the line?

Solution: Construct a profile on *AB* and draw the straight line *AB*. It will be the line of the railroad, on which the cuts and fills can be measured to the vertical scale assumed.

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6. In the above case could earthwork or trestles be saved if a maximum grade of 6% were allowed? Show how.

Solution: By reducing the grade at some places and increasing it to the allowable limit (say 6%) at others, it will be possible to reduce the height of cuts and fills (or trestles).

7. On the blackboard or a sheet of paper lay out the borders of a map. Put in their appropriate places the title and all the data that should appear on a map for military purposes. (Omit all topography and conventional signs.)

8. The following general forms of visibility problems are suggested. Each should be adapted to the map in use.

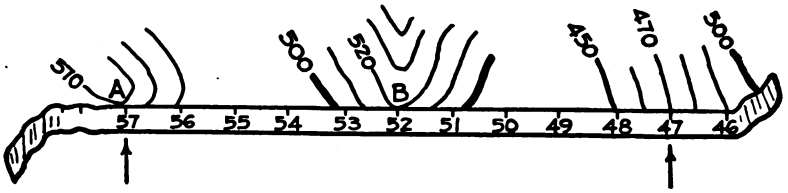

PLATE 14.—Solution of Visibility Problems with Rubber Band.

Determine whether the point *B* is visible from *A:* (1) By inspection of the map only; (2) by mental proportion; (3) by rubber band; (4) by graduated strip of paper; (5) by profile. If *B* is not visible from the ground at *A,* how high an observation tower is required?

A spur cuts off the view of a portion of the hillside beyond, from the point *A.* By drawing tangents to the contours of the spur (as in problem 4) determine the line separating the visible from the invisible area.

Trace the military crest on the ridge *AB,* by inspection of the map only.

What portions of a road *AB* must be screened to deny it to the view of an enemy on the ridge *CD?*

An observer at *A* is watching the road *BC.* The road is 20 feet wide, and the tops of motor trucks are 8 feet above ground. If the road screen is placed 50 feet from the edge of the road, how high should it be to prevent the observer from seeing the trucks? The enemy has now erected at *A* a tower 50 feet high. How much higher must the screen be? (Solve by profile.)

MILITARY SKETCHING.

INTRODUCTION.

It has been observed that precise surveying is a fine art. Precise maps are indeed necessary in war. But they should be prepared in advance during peace time, with military needs in view. Such precise surveying as is required after the outbreak of war is executed by the topographical experts of the Army, and the line officer has nothing to do with it.

But any junior line officer may be called upon at any time to make a rapid military *sketch* of a small area or a route of travel. Military sketching, like all other military operations, should be characterized by *speed* and *simplicity.* A high degree of accuracy is not necessary, and is in fact wasteful of valuable time. A military sketch should convey in readable form the required information. It is unnecessary that it be either very accurate or very elegant in appearance, but it must be ready when needed. However this, of course, does not mean that it should be *carelessly* executed. Legibility, neatness, completeness and *all the accuracy that is practicable in the time allowed,* are the essential requirements.

A number of small, portable instruments have been devised for the use of the military sketcher. Chief amongst these are the compass and clinometer (pocket sizes) whose uses are described herein. But while *desirable* these instruments are not *essential.* In time of emergency even these simple aids may be lacking, and the expert sketcher will be able to produce a satisfactory topographical sketch with no

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other equipment than his wits and training, and such simple articles as he can pick up in the company office. A bit of paper pinned to a board, a pencil and eraser, a "homemade" ruler or alidade, a couple of pins, a piece of string—these, with a keen eye, an alert mind, and the confidence that comes from practice, are all that are really needed.

Military sketching, like precise surveying, is a fine art. But the art consists in producing results sufficient unto the purpose and no more than sufficient, under difficult conditions, without adequate equipment, and *within the time allotted*. The power to do this may be acquired by any intelligent man, by a careful study of the principles and methods herein enunciated and prescribed, and by *thorough practice*.

The knowledge of ground forms that comes from practice in sketching is of immense value to all officers in the leading of troops and in the organization of the ground for defense. Military writers constantly tell us that both in attack and defense success depends on utilizing to our advantage the natural features of the terrain. We can utilize them to advantage only if we understand them. The troop leader must understand not only the ground forms under his eye. He must be able to look ahead, to imagine the terrain in which he will find himself, and how he will utilize it when he is there.

Having acquired the fundamentals of map reading and a general knowledge of scales, conventional signs, ground forms, etc., the student is now ready to take up practical instruction in the making of rapid military sketches.

The instructor should impress upon his students the purpose of a sketch, as distinguished from a map, the information to be conveyed, and the degree of accuracy which is desirable and possible. It is well to exhibit to the students a number of actual sketches of various kinds, to point out their characteristic features, and to tell them how long an expert requires to make such sketches in the field.

Rapidity and accuracy in the making of contoured sketches are dependent upon an understanding of *ground forms*. It should be carefully impressed upon the student's mind that the face of nature is not a mere jumble of confused and meaningless forms, but an orderly and logical recurrence of the same shapes, comparatively limited in number, closely related to each other, and formed in accordance with laws as unchanging as those which govern the contour of the human body. All hills and all valleys, or nearly all, were made in the same way. Wherever there are hills there must be valleys, and they always exhibit similar characteristics. Two landscapes, though differing widely in appearance, were formed by the same agencies and exhibit similar features, just as the head of a man and the head of a mouse, for example, though very different in size and outline, yet exhibit the same features, serving the same purposes. Grotesque forms are the exception in nature. We seldom see a hill that is not like some other hill that we have seen before.

The characteristic features which form the *skeleton* or *framework* of any terrain, to wit: The stream lines and the hills and ridges between them, should be called to the students' attention. The critical or controlling points of this framework should be indicated, and the student should be impressed with the ease with which the contour is filled in once the controlling points of the skeleton are fixed.

This conception of the orderliness, obedience to law and similarity of ground forms is best "driven home" by frequent exercises in *logical contouring*. Problems in logical contouring may be obtained from the Service Schools at Fort Leavenworth. The instructor may prepare new problems in any desired number by tracing the *master lines and critical points* from a section of a contoured map. These may be reproduced in any number by making first a tracing in ink, next a Van Dyke or Maduro negative, from which prints of *blue* lines on a *white* background are obtained. The Maduro and prints may be made in the college laboratory or at a local blue-print shop. Errors or mistakes by the students are made clear to them by superposing on their "logical contours" a tracing showing the contours as they actually exist.

It is considered inadvisable to attempt any actual sketching, or even to use the standard instruments in performing the fundamental operations of sketching, until

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the students have acquired a sound knowledge of ground forms, by frequent exercises in logical contouring. Any student who cannot satisfactorily solve problems in logical contouring will never become a successful sketcher, and any time spent in teaching him will be wasted.

The fundamental operations of sketching; making a scale of paces, measuring a distance, intersection and resection, orientation, location of position, measuring a slope, estimating distances and elevations, traversing, etc., should next be taught, and the students given ample practice in all of these operations. The use of the simple sketching instruments should be taught if such instruments are available. But the students should be shown that a sketch can be made without them. Some practice in lettering, including title, and drawing conventional signs to the proper scale, is very desirable. The students should be shown the proper pencils (of different hardness) to be used for different purposes.

All of this instruction (except drawing) may be given on the college campus, though a more diversified terrain should be used, if not too far away.

The students may next be required to make a sketch *without contours* of a limited area, such as a portion of the college grounds, or any other terrain nearby which lends itself to the purpose. If practicable two or more periods of instruction should be combined for this purpose. If this cannot be done the sketch may be started one day and completed on following days—though this is less satisfactory.

Next in order the student should be shown the ground forms as they exist in nature. The laws governing the structure of topography should again be explained and reviewed and illustrated by relief maps, the sand table and actual terrain. The instructor may tape out some contours on the ground, in order to visualize them, and require the students to do likewise.

This should be followed by some simple exercises in sketching characteristic forms, if terrain is accessible.

This progressive instruction, if intelligently and *entertainingly* carried out, will greatly stimulate the interest of the students. They will be desirous of a chance to practically apply what they have learned, by making a complete sketch under conditions similar to those which would be met in war time.

The instructor should next, if practicable, conduct his students to a piece of diversified terrain, preferably containing some woods and streams, but generally open and " easy " terrain. He should, if possible have previously sketched this area himself, distributing some blue prints of the sketch to the class. If the terrain cannot be sketched an " imitation " sketch may be made by enlarging the map. The instructor, accompanied by the class, should now proceed over the ground, following the same route as in making the sketch (which route may be staked out). At each station the instructor explains the operations to be performed and the features to be noted. He points out the streams and ground forms, the prominent points of the landscape, the positions to be occupied in contouring, etc. A half day or even more may well be devoted to this exercise. (In order to find a half day the students may be excused (if practicable) from a sufficient number of their practical hours during the week in order that they may devote an entire Saturday morning's work to this exercise.)

The students should now be ready to make their own sketches. If their interest has been stimulated they will be anxious to do so. The remaining periods of instruction should be devoted to actual sketching. In their first sketches the students should not be unduly " pushed " for time. More attention should be paid to systematic and accurate procedure. But the pressure should be gradually increased, with the ultimate purpose of causing every student, or the majority of them, to make a complete sketch within the time allotted by the instructor. Six hours for a position sketch of $\frac{1}{2}$ a square mile, or a corresponding time for a less or greater area, and about $1\frac{1}{4}$ miles per hour for a road sketch (on foot), are suggested as attainable by average students. No position sketch of an area greater than a square mile should be attempted, even by the most expert of the student sketchers. For the class generally, a lesser area will be better—$\frac{1}{4}$ to $\frac{1}{2}$ a square mile.

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It is realized that at many institutions, especially those located within the limits of cities, it may be very difficult, perhaps impossible, to carry out the program herein suggested. It should be done to the extent that facilities allow.

A sketch having once been started should be pursued continuously until it is completed, if at all practicable. And it is extremely desirable that the course in sketching should culminate with at least one complete sketch by as many students as possible. The completed sketch is a test of what the student has actually learned during the course, and the making of it gives him a confidence that cannot be acquired in any other way.

Accordingly the instructor should endeavor to obtain at least a half-day period for a complete sketch. If this be impossible, or if there is no suitable terrain which is readily accessible, the students, or such of them as are sufficiently interested, may be induced to devote one or more Saturday afternoons or Sundays to the purpose. If the instructor has made the course interesting, some at least will be willing to devote their holidays to sketching.

If the conditions are so unfavorable that no actual sketches can be made during the college year, an opportunity for this instruction should be provided during the R. O. T. C. summer camp.

Students who exhibit an aptitude for sketching should not be held back by those who do not. It is better to qualify at least a few good sketchers if possible, and such men should be given certificates that they have demonstrated their ability to make a sketch.

The foregoing remarks as to the conduct of the course in military sketching indicate what is desirable—a standard to be attained as nearly as possible. They are of course subject to modification according to the conditions which must be met at any particular locality.

As a final caution it must be repeated that military sketching is a practical art and can be acquired only on the ground. No amount of theoretical study will make a good sketcher unless it be combined with actual practice in making sketches.

The instruction must be systematic and logically progressive. It is of no use to attempt a complete sketch until the student thoroughly understands what he should look for and how to find it, nor until he is familiar with each of the fundamental operations involved in sketching. To jump from one subject to another without a progressive plan of instruction, will merely confuse the student. The lessons and suggestions for practical exercises which follow, are in accordance with such a plan of progressive instruction, which is summed up in the tenth lesson.

FIFTH LESSON.

A *military sketch* is a crude and hasty topographical map of a limited area of the terrain, or of a route of travel, executed by the characteristic methods of military sketching. It may be regarded also as a report of the topographical features of a certain area, in which the information gathered is conveyed graphically by means of conventional signs, instead of words. Such a sketch is used only when no good map is available, and the time and facilities for making an accurate map are lacking.

Classification of Sketches.

Military sketches are of two general classes, viz.: (a) *Area sketches* and, (b) *route sketches.* Area sketches include (1) *Position sketch.* In this, the most common form of area sketch, the sketcher has access to all parts of the area to be portrayed; (2) *Outpost sketch.* In this case the sketcher, travelling along in rear of an outpost line, sketches the area in front, which he cannot actually enter; (3) *Place sketch.* In this case the entire sketch of a limited area is made from a single spot. The *entire* area sketched may or may not be visible to the sketcher.

Route sketches are hasty maps of a road, or other route of travel (railroad or stream, etc.), and of a belt of the terrain on either side of the route.

A third form of sketch often employed for military purposes, is the *panoramic sketch.* This is not a map, but rather a picture or panorama in perspective, of the

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terrain as it appears to the eye of the observer from a certain point. It conveys certain information more readily than a map. Its greatest usefulness is in connection with the terrestrial observation of the activities of the enemy from a lookout or observation post.

Horizontal Detail and Ground Forms.

A sketch may exhibit the features of the terrain in their horizontal relation only, or it may include also the contours which portray ground forms. A route sketch is often not completely contoured, but indicates the ground forms approximately by means of *form lines* or *hachures,* with the elevations of the more important points. Form lines are simply contours without reference numbers which indicate the general nature of the ground forms, such as hills, ridges, valleys, etc., but not the complete details of their shapes. Hachures are a form of hill and valley shading which gives an approximate idea of the diversification of the terrain. Both of these devices are simply rough substitutes for contours, employed when there is not sufficient time nor information available for putting in the contours.

Scales and Vertical Intervals of Military Sketches.

The scales and vertical intervals usually employed in military sketching are:

a. For area sketches: Scale 6 inches equal 1 mile, V. I. 10 feet.

b. For route sketches: Scale 3 inches equal 1 mile, V. I. 20 feet.

(See also " The normal system "—post.)

Army Regulations have recently prescribed that route sketches shall be executed on a scale of 1 : 20,000, and area sketches on a scale of 1 : 10,000, with contour intervals of 10 and 20 feet, respectively. Inasmuch as the large scale maps are to be on this same scale, there would be the advantage that the area sketches would be comparable with existing maps, and data readily transferred from one to the other. Such sketches would have the disadvantage that they could not be scaled with an ordinary ruler, graduated in inches.

The Structure of the Ground. Erosion.

Although many agencies, volcanic, glacial, etc., have played their part in the creation of the forms of nature, yet in their final outline as they exist to-day, the majority of these forms are the result of *erosion.* The action of running water, continuing through the ages, has rounded off the hills and ridges, carved out the valleys, and given to both the characteristic forms in which they now appear.

As they have been shaped by the same agency all these forms exhibit similar characteristics, and a knowledge of their characteristics is essential to one who would become an expert sketcher.

Since running water is the sculptor of nature, the stream or drainage lines of an area form the skeleton of the ground, determining the positions of the valleys, and of the ridges and hills which lie between them.

Master Lines and Critical Points.

The stream lines together with the crest lines of the ridges and hills, constitute what are known as the *master lines* of topography, to which all minor details adjust themselves in a systematic and perfectly logical manner.

The *critical points* of these master lines are those at which occur a change of horizontal direction or a change of slope of the lines. If these points are determined, the master lines are readily plotted on the map. Some points are critical for horizontal location, others for vertical location.

The efforts of the sketcher are accordingly directed towards locating the *critical points of the master lines,* which he must learn by experience to look for and to recognize. Such points will include: Heads of streams, junctions of tributaries with main streams, hill tops, points of change of slope on ridge lines, points of change of direction of valley (stream) and ridge lines, etc. Both the horizontal position and the elevation of these points must be determined.

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Once these critical points are fixed, the contours representing the ground forms are readily sketched in, because these critical points fix the position of all less important details in the area.

The best results are obtained if the contours be sketched in sight of the ground forms they are intended to portray. But with the critical points determined and plotted, a very accurate representation of the terrain may be sketched without again seeing the ground, by one who is familiar with the laws governing ground forms, or the characteristics of contours, hereinbefore discussed. (Map Reading.)

Horizontal locations. Features other than ground forms, such as buildings, roads, railroads, woods, etc., follow no fixed natural laws in their location. The horizontal positions of all such features must be independently determined and plotted, as they are encountered. No special skill is required.

These features do not affect the location of the contours. Contour lines should never be drawn through or across buildings, roads, streams having an appreciable width, or lakes.

Characteristics of Streams and Ground Forms.

Some of the characteristics of ground forms are elsewhere discussed. Certain additional features which should be known to the sketcher are here noted.

The slope of streams is usually inversely as their size, that is the higher, smaller streams have steeper slopes than the larger ones below. The slope of a stream *usually* increases towards its upper end. Streams having water in them are of flatter slope than the dry gulleys or ravines in the same locality. Within the limits of an average sketch the water surface of a river having no falls nor rapids, may be assumed as practically level. It will hence be especially useful as a master line for topography. A small stream *always* flows into a larger. The main stream or drainage line in any area is the most important master line for the topography of that area. It should be identified and located as soon as possible.

Hill slopes are of three classes, uniform, concave and convex. Uniform slopes are indicated by equal spacing of contours, concave slopes by contours closer together at the top and farther apart at the bottom, convex slopes by the reverse of this. As the nature of a slope is of military importance it should be noted, since in the absence of any information to the contrary all slopes between adjacent critical points must be assumed as uniform.

A depression in the crest of a ridge is variously known as a col, saddle, pass or gap. It is indicated by a very characteristic appearance of the contours.

Very flat or gently undulating ground is difficult to contour, because the critical points are difficult to identify. It will usually be necessary to arbitrarily select a relatively large number of points.

An understanding of ground forms, and the laws governing them, and of the importance of the master lines and their critical points, is a necessary preliminary to any work in the field. It is useless to attempt an actual sketch until the student understands what information he needs for such a sketch. A knowledge of the instruments of sketching and the methods of using them is merely a means to an end, that end being the making of a sketch. The student should know the end in view in order to intelligently utilize his instruments to that end.

The nature of the information which must be gathered on the terrain in order to make a sketch is best impressed on the minds of the students by means of practice in logical contouring, which important subject is accordingly taken up thus early in the course.

We shall see later that in topographical sketching the sketcher first establishes the geometrical control which forms the general framework of his map, and enables him to place in their correct positions the critical points of the master lines of the topography. He then exercises his skill and knowledge of ground forms in selecting these master lines and critical points, which he fixes on his map by the aid of his geometrical framework or control.

The beginner almost invariably uses more points than are necessary, both for nis geometrical and topographical control, and usually wastes a good deal of time

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and becomes confused in consequence. As he gains experience he soon learns that comparatively few control points are really needed, provided they are skilfully selected.

The contours are usually sketched in the field, or " in sight of the facts," and when the sketcher can thus see the ground before him he will need only a few critical points to enable him to fill in the contours. However, if the necessary critical points have been selected, an expert sketcher can put in the contours very accurately, without again seeing the ground, by aid of his knowledge of the general characteristics of ground forms and the laws governing them.

LOGICAL OR MECHANICAL CONTOURING.

The process of sketching in the contours by the aid of located critical points alone, and without seeing the ground, is known as *logical* (probable) or *mechanical contouring*. It is a most valuable means of instruction, as it gives the student a practical acquaintance with ground forms and the laws governing contours. It also teaches him just which are the critical points in the topographical control, trains him to select all the really critical points which he needs, and to avoid cluttering his map and wasting valuable time by locating points which are not needed.

Practice in logical contouring is accordingly essential to become an expert sketcher, and considerable time and patience may well be devoted to it. The student should first solve some simple typical problems. He should then trace from a contoured map what he regards as the critical points, being limited as to the number he may select, and sketch in the contours from the points thus selected. His result should then be compared with the map. Finally the student should himself sketch a piece of terrain, locating the critical points of the topographical control, and fill in the contours without again seeing the ground. By such exercises the student will learn what points he has omitted which he should have located, and what unnecessary points he has wasted his time upon.

Plates 15 and 16 show in detail the progressive solution of a problem in logical contouring.

In *A* the sketcher has located the master lines of the area, which include the drainage system and ridge lines. He has also located a limited number of critical points, including the high and low points of the main stream, the elevations of the upper ends of its tributaries, the hill tops, and the points of important changes of slope on the crests of the spurs. This is the skeleton on which his sketch is hung.

In *B* he locates the critical points of all contours, which are the points where they cross the bottoms of the valleys (indicated by the stream lines), and the crests of the ridges.

The first step is to locate the contour crossings of the main stream. Its lower end is at elevation 790, its upper at elevation 850. As there are no waterfalls in the stream, there will be no great error if its slope is assumed as uniform from one end to the other. A more accurate solution will be obtained, however, if the stream is made slightly steeper at its upper end (contours closer together) as this is characteristic of small streams, though not invariably the case. The contour points are accordingly placed at 10 feet vertical intervals from 790 to 850, slightly farther apart below and closer together above. There would be no great error if they were uniformly spaced.

We now have the logical (probable) elevations of all points on the main stream, including the points where the tributaries enter. Having also the elevations of the upper ends of all tributaries we may now place the contour points on all the tributaries in exactly the same manner as we did for the main stream. We here perceive that it is usually unnecessary to take the *elevation* of the points where tributaries enter a main stream, provided we know the slope of the main stream. But the elevations of the upper ends of the tributaries are always required.

Ridges cannot, like streams, be assumed to have a uniform or gradually changing slope. They are subject to more violent changes, and the *points of change* must be located. Thus in the large ridge in the southeast corner, three changes of slope are

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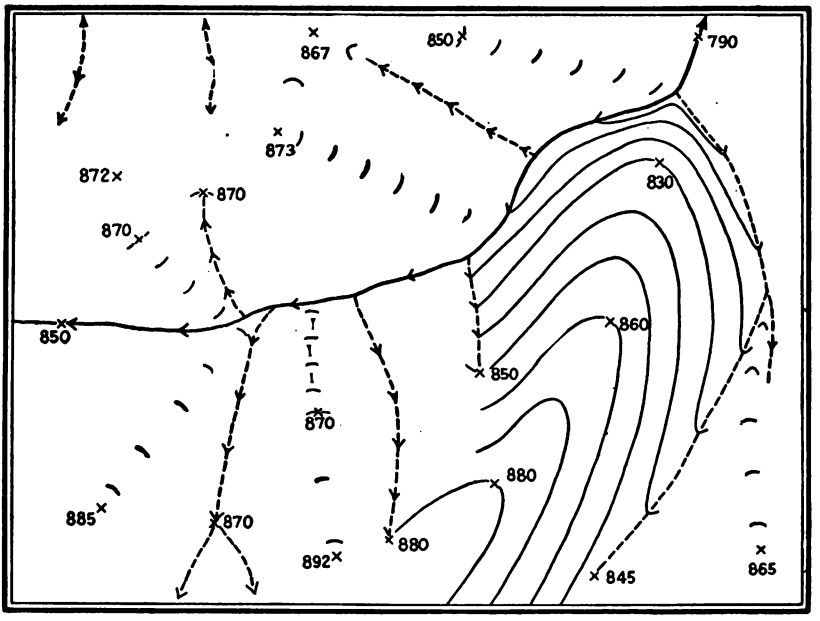

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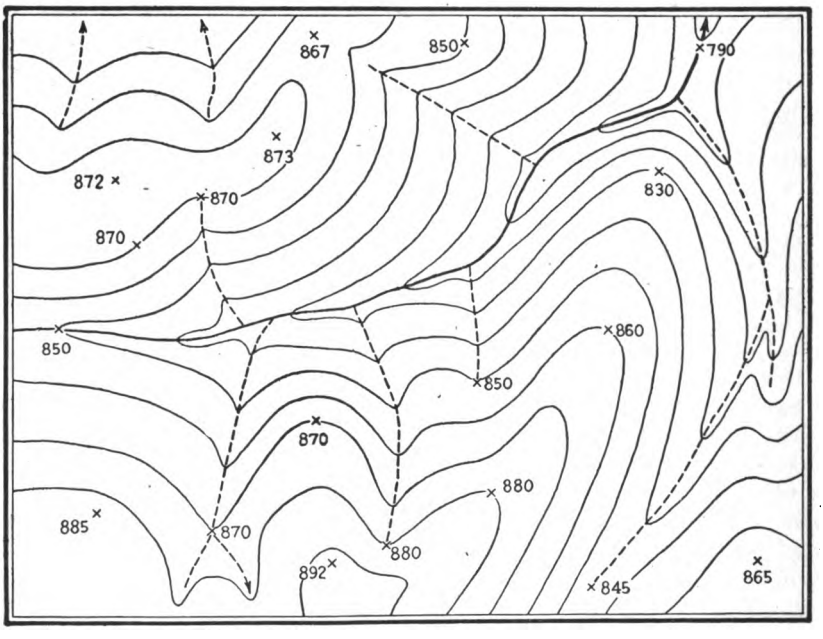

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PLATE 16.—Logical Contouring.

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Cover and shelter. All features which afford shelter from view or fire or from the weather, are of military importance. They include hill slopes, woods, towns and isolated buildings or groups of buildings. The nature of woods, dense or open, deciduous or evergreen, should be noted. The number of inhabitants and the nature of the industries will indicate the amount of shelter to be found in a town.

Obstacles. All features which might interfere with the movement of troops are of importance. They include streams, marshes, woods (especially with undergrowth), very hilly or broken ground, fences, etc.

Water supply. All sources of water supply should be indicated. They include running streams, lakes, and wells. Local water works, such as reservoirs, dams, pumping plants, tanks distribution systems are of importance.

Towns. The general nature of the buildings should be noted. Large and important buildings of any kind are separately indicated. The supplies of all kinds available should be ascertained. They are approximately indicated by the number of inhabitants, which should be noted on the sketch.

Agriculture and manufacture. Mineral resources. The nature and volume of the principal crops, the output of important factories, mines, oil wells, etc., are of importance as affecting the question of supply.

Landmarks. Prominent landmarks are of special value for purposes of travel, tactical operations and other activities. All such should be shown on the sketch.

The configuration of the terrain. This has its influence on every military activity. It is shown by contours. In addition to contours the elevations of hill tops and of certain important points, such as road junctions, should be indicated by numbers giving their height in feet. Hills and road junctions are often designated by these heights, as " Hill 203," " Road Junction 165."

Notes.

There should be on hand for exhibit to the students a number of typical sketches of the various classes.

The influence of erosion in forming the ground may be shown by models and on the sand table. In order to bring out the characteristics of terrain it is necessary that the vertical scale of such models be exaggerated.

The importance of the master lines and critical points may be made clear to the students by sand table models and contoured maps. The skeleton which is formed by the main drainage line of an area, and its tributaries, should be pointed out.

The different classes of slopes and their military significance should be indicated.

The most important practical instruction prior to taking up actual work on the terrain, is that afforded by logical contouring, and a large part of the time available should be devoted to this exercise. This should be continued throughout the course, whenever practicable, as on rainy days when outdoor work cannot be done. The successful solution of problems in logical contouring is conclusive proof that the student has grasped the fundamental principles of the art of sketching.

SIXTH LESSON.

Accuracy and legibility of military sketches. It is not necessary that a military sketch should be either geometrically accurate or elegant in appearance. It is admittedly a crude map. But it should be neat in appearance and easily legible. And it should convey all essential military information with sufficient accuracy for the purposes for which the sketch is used. If the map is not legible it will fail to convey the necessary information to the reader. Moreover, the effort to read it will irritate him, cause him to doubt the accuracy of the sketch, and possibly to discard it as useless.

Use of conventional signs and explanatory notes. The essential features of the sketch should stand out clearly and not be obscured by unimportant details. Conventional signs should be used only to the extent actually necessary. Standing crops may be better indicated by writing in the name of the crop, as " Corn," than

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by filling the field with the symbol for corn, which will consume time, and probably clutter and obscure the sketch. A wood may be indicated by putting in its irregular outline and writing "dense wood" or "open wood" inside. In the case of important features for which no conventional sign is *commonly* employed, or where the sign alone does not convey all the necessary information, a note should be placed on the sketch, or a reference number to a note on the margin or at the bottom of the sheet. For example, in the case of a stream, the width of the stream, its depth, the nature of the bottom and the height and steepness of the banks, are all matters of military importance, which should be covered by the necessary notes since the conventional sign does not convey the information. Bridges on important routes should be described by abbreviated notes, giving the type of bridge, its essential dimensions (length, width, height above water), probable safe load, and condition, as "good," "fair" or "bad." Thus: "w. tr. $\frac{24 \times 10}{12}$, fair," means "wooden truss bridge 24 feet long, 10 feet wide, 12 feet above the water, in fair condition." (See also Plates 5 and 39.)

Lettering and titles. Before attempting a complete sketch in the field the student should practice drawing imaginary landscapes, until he can make a neat and legible sketch, using all the ordinary conventional signs and characteristic notes.

The lettering of a sketch should be simple and legible. Either vertical or sloping letters, and either small letters or capitals, may be employed, as in Plate 18. In practicing lettering the student should draw light guide lines to insure good alignment and uniform height of letters. After a little practice he will be able to dispense with these lines.

Neat handwriting or script, while not to be desired, is preferable to poor lettering. The size and spacing of conventional signs should be appropriate to the scale of the sketch. Lettering should generally be as small as legibility permits. All lettering should be placed so that it can be read when the north edge of the sketch is up. Lettering in the body of the sketch may be in a diagonal line, but should never be upside down.

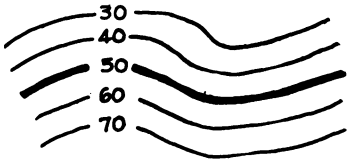

PLATE 17.

Contours should be numbered as frequently as necessary for identification. Every fifth contour should be made with a heavy line. The contour reference numbers are written in breaks in the contours. (Plate 17.)

Every sketch should have a title, setting forth the character of the sketch, the locality, the name, rank and organization of the sketcher, the date, reading scale, vertical interval, and any other information that may be essential. The working scale should not appear on the sketch.

The title should preferably appear in the lower right hand corner of the sketch, but may be placed elsewhere if room is not available in this corner.

The Plane Table Method.

Military sketching as we have seen, is a crude method of surveying. For ordinary surveying two general methods are employed. In one, known as transit surveying, the necessary measurements of distance, direction and elevation are made in the field by means of the transit and stadia (or tape), and recorded in a note-book. They are then plotted, or made into a map, indoors. In the other method, known as plane-table surveying, the drawing board or plane-table is set up in the field, and the various features of the terrain are plotted immediately after their position is determined. Each method has its advantages, but for topographic surveying the plane-table method is now recognized as being the simplest, easiest, most direct, and especially the most rapid. The keeping of voluminous notes, apt to be misinterpreted, is avoided, and the map is made "in sight of the facts." Military sketching is an adaptation of the plane-table method, in which the map is completed outdoors or in the field.

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The Control or Framework of the Sketch.

In all surveying, including military sketching, the order of procedure is first to establish the *control* or skeleton of the map, and next to fill in the details of the topography, hanging them upon the control.

To establish the control the sketcher selects a number of prominent and important points throughout the area to be sketched, and determines their horizontal positions and vertical elevations with as great a degree of accuracy as is practicable within the time and with the facilities at his disposal. On the skill with which these points are selected, and the accuracy with which their positions are determined and plotted, the excellence of the final result will very greatly depend.

ROAD SKETCH
from
BALTIMORE to CAMP MEADE, MD.
JUNE 14, 1921.

By
1st Lieut. A.B. Jones, 18th Inf., U.S.A.

SCALE: 3 INCHES = 1 MILE V.I. = 20'

100 0 500 1000 YARDS

PLATE 18.

With a good control the chance for any large errors is almost eliminated. The measurements made for filling in detail are relatively small, and an error or mistake in one measurement in one locality will not affect another measurement elsewhere. But if the control is faulty no amount of care in filling in details will compensate therefor, and an accurate map is out of the question.

To illustrate what is meant by this, let us assume, that *A* and *B*, Plate 19, are two control points of a sketch (scale exaggerated). The house at *c* is located with reference to the point *B*, and the road *de* is located with reference to the point *A*. There is little chance of any great error in locating the house *c*, as the line *Bc* is very short. Even if we made an error of 25%, the house would still be fairly close to its true position. It might, in fact, be drawn in by eye alone, without actual measurement, and the result would be sufficiently accurate for military purposes. Moreover, no matter how great an error we may make in locating the house *c*, this will not in the least affect the location of the road *de*, as the latter location is entirely independent of the former. But if the points *A* and *B* are not correctly located, both the house and the road, and everything else nearby will be in the wrong places. Moreover, an error in control is apt to be *cumulative*. That is if one point is incorrectly located, or one important measurement improperly made, it may affect the entire sketch and utterly destroy its accuracy. Thus if we make an error of 50% in the measurement of *Bc* we would have the house *c* and some of the topography near it a little out of place, but the rest of the sketch would not be affected. But suppose that we should make an error of that amount in measuring the length of our base line, or the primary traverse on which our control depended. Then every point on the map would be far from its correct place, and as the sketcher proceeded to fill in his detail he would soon run into so many difficulties and become so confused that he would be obliged to abandon all his previous work and start over again. Distances, slopes, elevations,

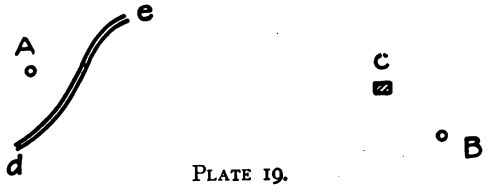

PLATE 19.

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etc., should never be estimated *in establishing the control,* but should always be measured with care. Once a good control is established most of the filling in may be done by estimation.

It will thus be apparent that the control of a sketch, or the location of the critical points on which the other features depend, should be made with all the care that is possible. The filling in of details requiring only short measurements, or in many cases merely an estimation of distance and elevation, may be made with great rapidity and without fear of any serious error, since no error in filling in can have more than a local or limited effect.

For the beginner it is well to put in the control first, and when this has been completed to fill in the details. The experienced sketcher conducts the two operations simultaneously, that is at each station occupied he fills in more or less detail, based on the control already established. But in no case should filling-in be carried ahead of control.

Geometrical and Topographical Control.

It should be noted that in a topographical map there are two systems of control. The first may be called the *geometrical* control. It includes a number of carefully located points in various parts of the area, by reference to which other points are located. These are usually prominent points easily seen and identified, but they are not necessarily nor even usually the critical points which fix the contour of the ground. They are selected primarily with a view to facility and rapidity in establishing the geometrical control. Geometrical control includes both horizontal and vertical control. Often the sketcher will use the same point for both horizontal and vertical control. But some points will be used for horizontal control alone and others for vertical control alone. A point used for vertical control must have both its horizontal position and its elevation determined. But if used for horizontal control only, its elevation need not be accurately determined.

The second system of control may be called the *topographical* control. It includes the critical points and lines which determine the contour of the ground, such as hill tops, ridge lines, points of change of slope, stream and valley lines, etc. The points and lines which constitute the topographical control should be carefully located, both as to horizontal position and elevation, but as their influence is local only, they need not be fixed with as great accuracy as the geometrical control, and in some cases their positions may be estimated by reference to a carefully established point of the geometrical control.

Reference points and critical points. As the geometrical and topographical control do not serve the same purpose, the points which constitute the two systems may or may not coincide, and in fact generally do not. This is well indicated by reference to Plate 20. The points *B, C* and *D* are all critical to the topographical control, *B* because it is a hill top, and *C* and *D* because they are points of change of slope. These points should be fixed if the contour of the hill is to be correctly portrayed. But none of these points are suitable for geometrical control because they are not definite points which can be located from a distance by sighting from other points. The exact positions cannot be determined until the sketcher has arrived in the locality.

On the slope at *A* stands a water tower which is visible from every direction for miles around. This prominent and easily identified object will be of great assistance to the sketcher as a reference point for resection to locate other points in the area. He will certainly include it in his geometrical control. Upon arriving at the hill he will locate *B, C* and *D* by reference to *A,* which will already appear upon his sketch. But the point *A* is of no value to the topographical control as it is not a critical point of the hill form.

Working Scales.

The subject of scales has been discussed under Map Reading. A *reading* scale for either a map or a sketch should be in the units ordinarily employed for measuring distances on the ground, such as yards or miles.

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A *working* scale for a military sketch is that employed by the sketcher in making his sketch. Usually it would not appear on the completed sketch. The unit for such a scale would be that actually used by the sketcher in measuring his horizontal distances. The units usually employed in military sketching are as follows:

For area sketches, or route sketches on foot: The sketcher's *stride,* or double pace, or the distance between successive prints of his right foot while walking at his natural gait. For route sketches mounted: The distance traveled by a horse in one minute, both at a walk and at a trot. For route sketches made by vehicle: (a) For a wagon, the circumference of one of its wheels, or the distance passed over in one revolution of the wheel. If brakes are applied to the back wheels the front wheel should be used. (b) For an automobile, the unit of its speedometer, usually miles and tenths of a mile.

Making the Working Scales.

As no two individuals have exactly the same length of stride, each sketcher should make his own scale of strides. For this purpose a carefully measured course is laid out. It should be neither too long nor too short, preferably not less than half a mile and not more than two miles. The length of the stride will of course vary with the nature of the terrain over which the sketcher walks. On a smooth level road his stride will be longer than over rough country and up and down hill. An average piece of terrain, similar to that which is to be sketched, should be selected for the measured course. For a scale for road sketching only, the course may be entirely on the road. Generally it will be across country.

The student endeavors to walk at his natural gait over the measured course. No attempt should be made to take a uniform stride or to regulate the length of the step. He should walk as he always does. Having walked the distance out, and counted his strides (double paces), the student returns over the same course, again counting his strides. The pacing should then be repeated, giving at least two determinations in each direction. If the four results are fairly close, their average may be accepted. If they vary considerably the student should pace the course several times, and take the average of all results, dividing the total distance walked by the total number of strides.

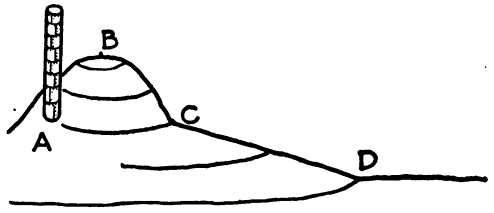

PLATE 20.—Critical Points and Reference Points.

Having determined the length of his stride the student must next construct a scale of strides to the assumed representative fraction of the sketch. Assume that the scale of the sketch is to be 6 inches equal 1 mile, and that the length of the stride is 59 inches. One thousand strides would be 59,000 inches on the ground, and since the R. F. of the sketch is 1/10,560, this would represent 59,000/10,560 equals 5.6 inches. Lay off 5.6 inches on a slip of paper and divide it into 10 equal parts. Each will represent 100 of the student's strides to the scale 6 inches equal 1 mile. One of these parts should be divided into 10, as an extension to the scale, reading to 10 paces, or into four, each reading to 25 paces. Printed scales for strides of any length, for scales of 3 inches and 6 inches to the mile, are issued by the Army Service Schools, Fort Leavenworth. These may be pasted on the alidade.

The error in measuring distances by pacing should not exceed 3%.

Rating the gait of a horse. Horses are rated for both trot and walk. The trot is the habitual gait for sketching, but to avoid undue fatigue the horse should be walked occasionally, especially in moving up or down a steep grade.

As it is impracticable to count the strides of a horse (though of course it is possible), he is rated according to the time required to pass over a given distance. The pace of a horse varies considerably, depending upon whether he is fresh or tired,

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whether he is going away from or returning to his stable, whether he is going up or down hill, whether he is alone or in company with other horses faster or slower than himself. The sketcher must learn by practice the normal gaits of his horse, and urge him or hold him back, if he is traveling too slow or too fast. With careful rating and handling, horses will furnish measurements with an error of not over 5%. The unit of measurement for a scale of a horse's pace is the distance traveled in one minute.

If it should be necessary to use an unrated horse, his speed may be assumed as 1 mile in 8 minutes at a trot and 1 mile in 16 minutes at a walk. These are easy gaits to which any horse may be held.

The ratings for man or horse having been made, they should be tested or checked by measuring some of the early sketches made with their ratings.

It is of the utmost importance that the sketcher's mind be not obsessed, or too much occupied with the effort of counting his strides or timing his horse. The counting should become almost sub-conscious, so that the sketcher may devote most of his attention to observation of the terrain over which he is passing. This will be greatly promoted, of course, by the use of the pace tally and stop watch.

Odometers. Revolutions of the wheel of a wagon are counted by means of an odometer. It is very desirable to have a type of odometer which can be read from the seat. One which must be removed from a case for each reading is such a nuisance as to be almost useless for sketching.

Horizontal and actual distances. It is to be remembered that all distances shown on a map are horizontal measurements. To obtain the *actual* distance between two points separated by hills and valleys, a calculation would be necessary. Precise surveying takes account of the difference between horizontal and actual distances. Except on very steep slopes, however, the difference is too slight to noticeably affect the accuracy of a military sketch, and it is always assumed that the actual distance as paced by the sketcher on the ground, or otherwise measured, is the same as the horizontal distance to be shown on the sketch. In case the sketcher has separately rated his stride up and down hill and across country he may apply these rates. Such refinements are not essential.

Notes.

Practical instruction in logical contouring may be continued in the practical periods available.

The students should also be given practice in the technique of drawing a sketch on a scale of 6" equal 1 mile, including the common forms of conventional signs, notes, lettering and titles.

It is best not to copy an existing sketch. The instructor should describe to the students, with the aid of diagrams on the blackboard, an imaginary piece of terrain, and cause them to draw it from his description.

The first efforts will naturally be crude, and must be improved by practice. Students who are not apt in making the conventional signs and lettering, should be urged to practice in their spare time and submit their results for criticism.

The instructor should illustrate briefly, by the sketching board, the methods of plane-table surveying.

The importance of accuracy in fixing the control of a sketch and the difference between geometrical and topographical control, should be impressed on the minds of the students.

The preparation of working scales by pacing is a matter of great importance, and will be of interest to the students as the first step in their outdoor work. Exercises in the construction of scales were given in the course in map reading, and may now be repeated to refresh the students' minds.

The rating of horses for mounted road sketching will be out of the question at most institutions, but the students should know the way it is done.

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SEVENTH LESSON.

Direction or Orientation.

It is of course essential that the sketcher shall at all times know or be able to determine the *direction* (azimuth or bearing) of all lines on the ground. The most usual means of doing this is by the compass, as described in the course in map reading. The compass should always be used, if one is available, as it is the most rapid

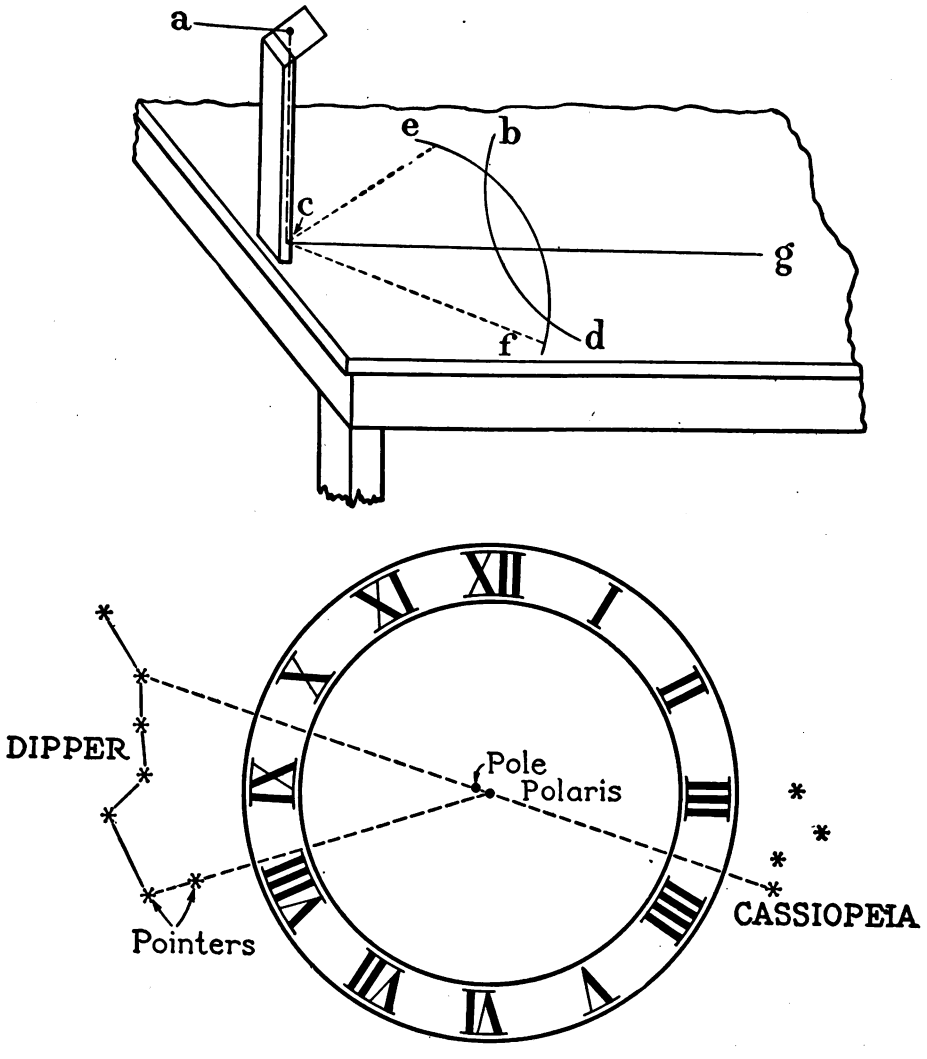

PLATE 21.—Direction by the Sun (Upper); and by the Pole Star (Lower).

and satisfactory means of orientation. But it is possible to determine direction and to make a sketch without the compass.

Direction by the sun. On a level table, erect a post *ac* (Plate 21) 18 inches long for short days (winter) and 24 inches for long days. At the top of the post place a sheet of paper or a piece of tin, having in it a hole, *a*. For about half an hour before and half an hour after noon, mark at intervals of 10 minutes the position of the spot of sunlight from *a*, on the table. Connect these points thus plotted, forming the curve *bd*. From *c*, on the table immediately beneath the hole *a*, strike a circular

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arc, *ef*, with any radius, intersecting the curve *bd* at *b* and *d*, near the edges of the board. Draw the line *cg*, bisecting the *circular* arc *bd*. It will be the true meridian.

Direction by the pole star. The true north pole is on a line joining the pole star (Polaris) with the second star from the end of the handle of the great dipper (Plate 22). Accordingly when this star is directly above or directly below the pole star, the latter is due north of the observer. Drive a stake at the observer's position. Place a man holding a candle (or electric flash light) as far north as he can conveniently be seen. Move him until the candle is directly under the pole star as seen from the stake driven (the eye is very sensitive to verticality). By means of a plumb bob, or by dropping a stone, set a second stake in the ground immediately below the candle. The line established by these two stakes will be the true north and south line, with sufficient accuracy for the purposes of military sketching.

As the distance of the pole star from the pole is only a little over 1 degree, no great error will result if this determination of direction be made at any time that the pole star is visible. If the position of the dipper be noted a correction can be applied if desired. (Plate 21.)

Direction by watch. To determine direction in the day time, point the hour hand of a watch, held horizontally, at the sun. Half way between the hour hand and XII o'clock on the dial will be (approx.) the true north and south line. As to which end of this line is north and which south, it is to be remembered that the sun is in the east in the morning and in the west in the afternoon. The *south* end of the line in the morning will be in that portion of the watch dial from VI on to XII (p. m.) and the opposite for the afternoon. The earlier in the morning or the later in the afternoon the more accurate will be the observation. This method is crude and approximate only, but sufficiently accurate for sketching purposes.

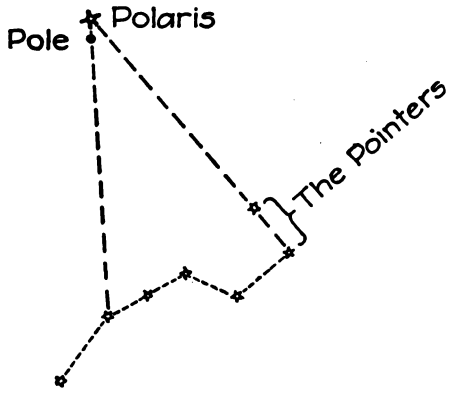

PLATE 22.—Direction by the Pole Star.

Orientation by backsight. Having by one of the preceding methods laid out a true north and south line on the ground, the sketcher may now orient his board, with its edge parallel to such line, to start his sketch. He next lays his alidade on the board and sights to the next point in advance, drawing the line of direction to such point. Having completed his operations at the point of beginning he proceeds to the advanced point. Here he lays his alidade along the line joining the advanced point and the point of beginning, sights *backward* along the alidade, and rotates his board until the point of beginning is in line with the edge of the alidade. The board is now again oriented. In like manner it may be oriented at each successive station occupied. Any line already drawn on the sketch connecting a point as *P*, with another point as *R*, visible from *P*, may be used to orient the board at *P*. This method is called *orientation by backsight.* (Plate 23.)

Sketching without a meridian. A sketch may be made without determination of the north and south line, and without a compass. The direction of the first line of the traverse is assumed in approximately its correct position as nearly as the sketcher can determine from his general sense of direction. The traverse is then continued by orientation by backsight. The magnetic meridian may be placed on the sketch after its completion, whenever a compass is available. To do this set up the board at any point shown on the sketch, and orient it by a sight on any other located point. Then place the compass on the board, rotate the compass box until the needle reads north, and draw a line along the east or west edge of the box. It will be the magnetic meridian of the sketch. If the compass case is round, place it on the oriented board and by eye draw a line parallel to the needle.

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Orientation by compass or declinator. To orient the sketching board by compass: Set up and level the board. Place the compass with the left edge of the box parallel to the left edge of the board (or parallel to the magnetic meridian of the sketch if this be not parallel to the edge of the board), and rotate the board until the north end of the compass reads *N* on the compass dial or swings equally to both sides of north. To orient by the declinator: Having leveled the board, rotate it until the declinator needle swings equally on either side of its center line, or comes to rest thereon. In both cases it is necessary to have the board so nearly level that the magnetic needle does not touch the glass which covers it—in other words it must swing freely.

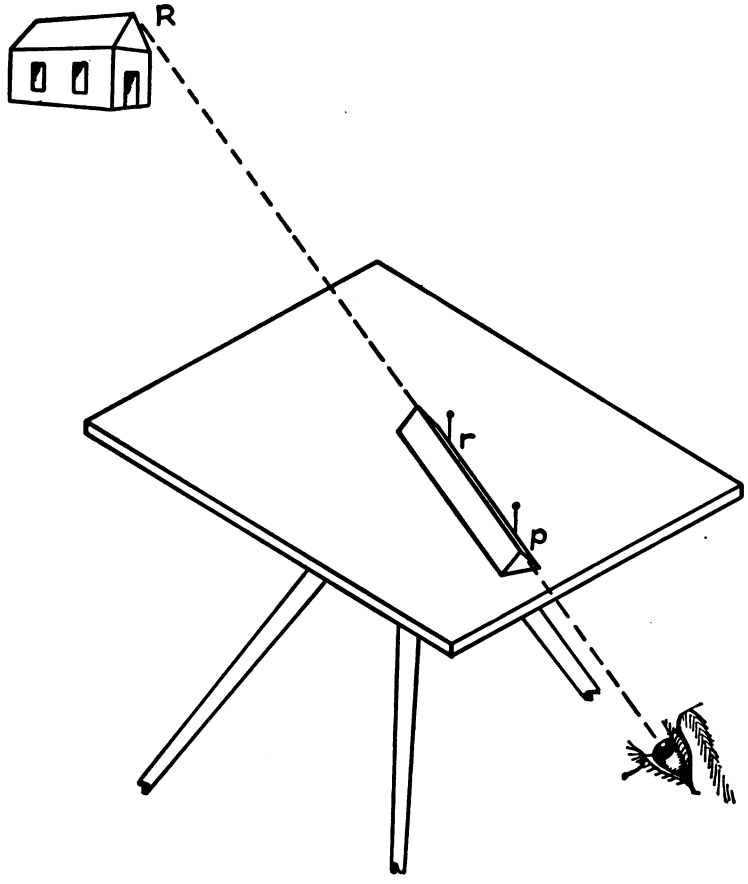

PLATE 23.—Orientation by Backsight.
The board is set up at *P*, whose plotted position is *p*. Stick pins in *p* and *r* (plotted positions of *p* and *r*). Lay the alidade against the pins and rotate the board until *R* is in line with the edge of the alidade.

Orientation by compass, occasionally checked by backsight, or vice versa, will be the usual method. The other methods described are used only when no compass is available or when local attraction makes the compass unreliable.

Instruments Used in Military Sketching.

We have pointed out that the fundamental operations of sketching are independent of the instruments employed. A skilful man can make a good sketch with no equipment other than he can pick up in any office. It is important that this should be fully understood, and that the student should free his mind from the idea that sketching is a mysterious art, involving the use of complicated instruments, and impossible

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to apply without these instruments. A knowledge of the fundamental operations of sketching, a familiarity with the natural laws governing the forms of nature, and the facility in interpreting them which comes from practice, are of far more importance than the instruments employed.

A great many instruments have been devised for the use of the military sketcher, and there is a tendency on the part of the beginner to overload himself with a variety of instruments to meet every possible demand. As he becomes more skilful he discards most of them.

The purpose of these instruments is to increase the speed and accuracy of operations which may be performed without them. Some of them serve their purpose well and have come to be recognized as standard. They should be employed when they are available.

The principal instruments employed in sketching are the following:

Sketching board.
Compass or declinator.
Alidade with scales.
Clinometer or slope board.

The above are the more essential instruments. Other instruments which are occasionally employed are:

Pace tally.
Stop watch.
Odometer or speedometer.
Aneroid barometer.
Range or distance finders.

Brief descriptions of these instruments follow:

Sketching board. This is the military form of plane-table. A great variety of sketching boards, more or less complicated, have been devised. The only essential is a flat board to which drawing paper may be attached by thumb tacks.

A convenient size for field use is 12×12 inches. Smaller boards are sometimes employed for mounted sketching. If the board is made about 13×14 inches there is room for a sheet of paper 12 inches square, with additional length and width for attaching to the board, and for a declinator or magnetic needle, in a trough at the edge of the board. Anything larger than this is awkward to handle. (Plate 24.)

A tripod with extensible legs, to which the board is attached by a screw on the under side, is a most desirable convenience. The attachment should permit the board to be rotated at will, or clamped firmly in any position. Boards for mounted sketching may be attached to the wrist by a strap on the under side. The board should be provided with a string, passing through diagonally opposite corners, by means of which it may be supported when the tripod is not used. The string is passed around the sketcher's neck and the board held against his stomach, in a horizontal position.

The declinator, sometimes provided, is a magnetic needle, set in a trough at the edge of the board. It is used to orient the board, setting its edge parallel to the magnetic meridian.

If the sketching board as issued by the Government or sold by a number of commercial firms is not available, a "home-made" board will be found quite satisfactory. It should be of good, seasoned wood, $\frac{3}{4}$- to $\frac{7}{8}$-inch thick and dressed smooth on both sides. The board should be of soft wood (white pine, poplar, etc.), which thumb tacks and pins will easily penetrate. To prevent warping or splitting of a board which is to be used for some time, strips, preferably of hard wood, about a half inch wide, should be nailed (or nailed and glued) across both ends of the grain. A coat of shellac or varnish will exclude moisture, but is not really necessary.

For such operations as require careful leveling and orientation of the board, and in the absence of a tripod, it may be placed on top of a wall or box, or any other level surface of the proper height, or if necessary, on the ground. For filling in details the sketcher may hold the board against his body, if standing, or on his knees or lap, if sitting.

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Compass. Whereas in precise surveying true north and south lines are used for orientation, in military sketching, for rapidity and convenience, all directions are measured from the magnetic meridian of the locality, and are determined by means of the compass.

The instrument was briefly described in the course in Map Reading. Its essential parts are the magnetic needle, the pivot, the graduated dial, the needle stop and the case. The stop serves to clamp the needle against the case when not in use.

A great variety of types of compasses are in use. The best type for military sketching is one with a needle of moderate length, a fixed dial, graduated to read both azimuth and bearing, all in a square case. Some compasses are provided with sights, by means of which the bearing of a line may be determined with considerable accuracy. In the prismatic compass the bearing of the line may be read while sighting along it. All military compasses have the zero of azimuth at the *north* point.

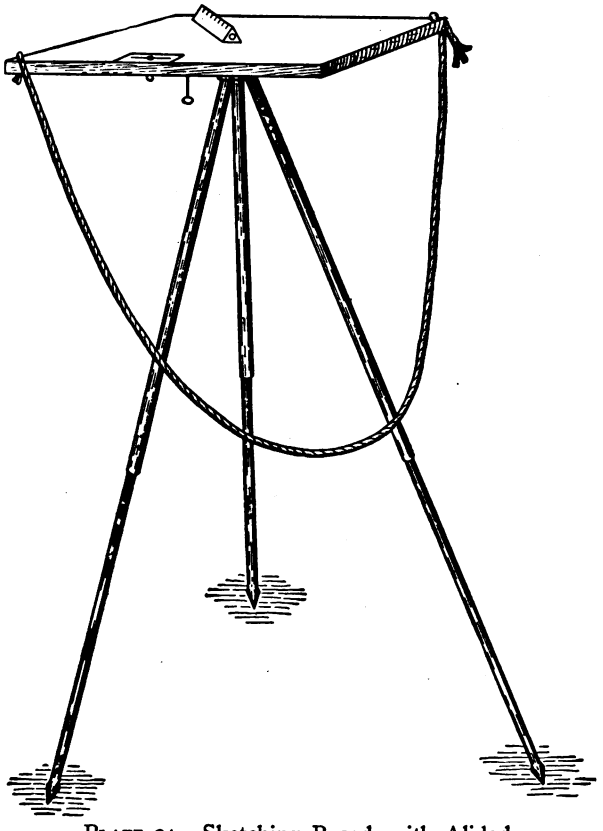

PLATE 24.—Sketching Board, with Alidade, Declinator and Tripod.

For military sketching no graduated dial nor sights are really necessary. The only essential parts of the compass are its needle and pivot, by means of which the sketching board is oriented. All lines are then drawn in their correct position by the alidade alone. This simplest form is found in the declinator (see ante) which is a part of some sketching cases. Plate 25 shows a typical form of box compass, commonly employed in sketching.

Alidade. The alidade generally used is a three-cornered wood ruler for sighting and for ruling straight lines. Metal alidades, with vertical sights at each end, are sometimes employed. They are of course more accurate than the three-cornered ruler. The sights fold down like the rear sight of a rifle, allowing the instrument to be carried in a flat leather case.

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The three-cornered wood alidades may be made by sawing a square strip of wood in two. A very good wood alidade may be purchased at slight cost from the Army Service Schools at Fort Leavenworth. Paper scales of paces, yards, slopes, etc., may be pasted to the alidade, there being room for 6 scales, 1 on each side of the 3 edges.

The proper dimensions for an alidade for the military sketcher are—width of face about $\frac{3}{8}$ inch, length 6 to 8 inches.

Clinometer. The clinometer is an instrument for measuring slopes or grades. Three types are in common use, viz.: The service clinometer, the Abney and the Beebe. (Plate 26.) The service clinometer operates by gravity, the reading is given on a dial, and may be seen while taking the sight. In the Abney clinometer the horizontal is fixed by the bubble of a level tube, and the readings are taken on a vertical limb, like that of a transit. The Beebe clinometer is a hand level with graduations on its object glass. It has the advantages of simplicity, but its range is limited, and it is necessary to make two or more readings and add them in the case of steep slopes.

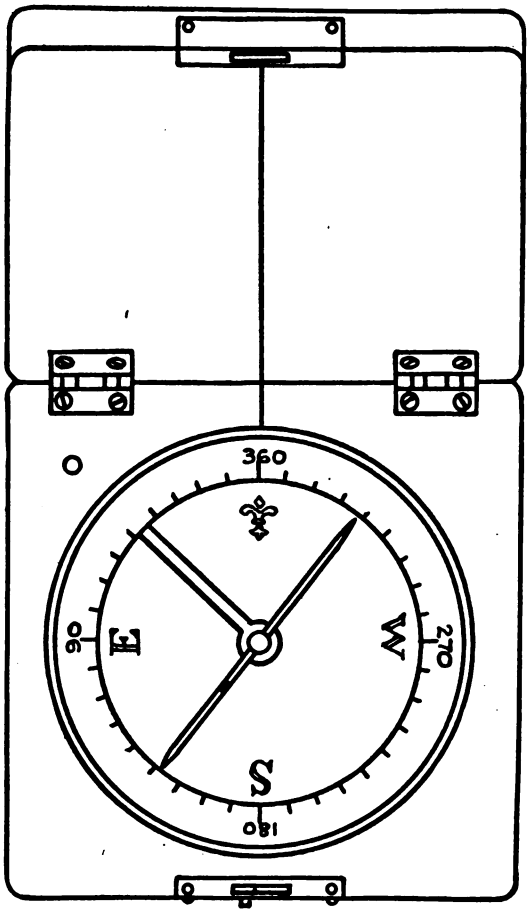

PLATE 25.—Compass in Box.

Clinometers may be graduated in degrees or in per cent. The latter is preferable as simplifying calculations.

A clinometer should be tested to determine whether it reads correctly. This may be done by sighting from marks made on two trees, about 100 feet apart. Hold the clinometer against the mark on tree *A* and sight to the mark on tree *B*, recording the readings. Then reverse the process. Suppose one sight to have been plus 3% and the other minus 5%. Then the slope between the two marks is 5 plus 3 divided by 2 equals 4% (plus or minus). Hence, all plus readings are 1% too small and all minus readings 1% too great. All readings should be corrected accordingly, or the clinometer may be adjusted until it reads correctly.

Slope board. In the absence of a clinometer slopes may be read by means of a slope board (Plate 27). This is readily improvised by attaching a cord with a weight at the bottom, to one edge of the sketching board, and properly graduating the opposite edge in degrees or per cent. Holding the board in a vertical plane, the sketcher sights along the edge to the point whose slope or grade from his position is desired. While sighting he clamps the cord against the edge of the board with his thumb, then lowers the board and takes the reading.

The sketching boards issued by the government or purchased from commercial firms are often graduated to read slopes. To construct a slope board proceed as follows:

From the point of suspension of the plumb line *P* (Plate 27) draw a line *PQ* parallel to the edge of the board, having first tested the board to make sure that the

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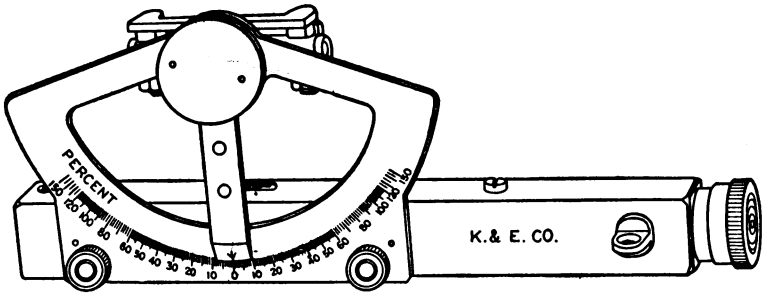
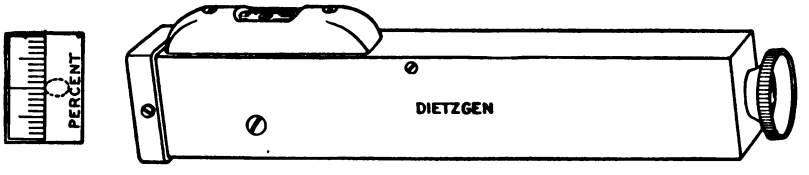
corner *C* at least, is perfectly square and the edges *BC* and *CD* perfectly straight (test with a carpenter's square).

From *P* as a center with a radius of 5.73 inches, strike a circle *FG*. From either side of the line *PQ* mark off divisions of 1/10 inch. Each of these will correspond to one degree, minus on one side, plus on the other. Draw lines from *P* through the points of division until they cross the lower edge of the board, and graduate them on both sides of the line *PQ*.

To construct a slope board to read percentage, lay off on the lower edge of the board, on either side of *PQ* divisions equal to 1/100 of the line *PQ*, and draw lines from *P* through these points of division, each of which corresponds to 1%. (Plate 28.)



ABNEY CLINOMETER



BEEBE CLINOMETER

PLATE 26.—Clinometers.

Pace tally. This is simply a counter, operated by pressing down a lever while the counter is held in the palm of the hand. It is used to count strides. The sketcher holds the tally in his left hand, and presses down the lever at the end of each forward swing of his left arm, which will be the same instant that his right foot strikes the ground. With this instrument the counting of strides becomes practically automatic, leaving the sketcher free to devote his entire attention to the features of the terrain.

Stop watch. Odometer and speedometer. These instruments require no description. The stop watch is used for mounted sketching with a time scale for the horse. The odometer and recording speedometer are used for measuring distance in route sketching by wagon or automobile, respectively.

Aneroid barometer. This is a small instrument, having a graduated dial and pointer which indicates the elevation of the spot on which the observer stands. The pointer is operated by changes in the pressure of the air. As the pressure of the air depends not only on the elevation, but also on the temperature of the air and of the instrument, the humidity and latitude, the aneroid barometer is of little value in

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determining absolute elevations. But if the readings for different localities are taken at short intervals during which there has been little or no change in the temperature and humidity, the instrument gives with fair accuracy the *difference* of elevation of two points. It is little used in area sketching, but is often employed in route sketching. The ease with which the elevation is determined by simply reading the instrument is a great advantage.

In starting a route sketch the instrument is set to read the known or assumed elevation of the starting point. Whenever, during the journey, a point of known elevation is reached, the instrument should be reset to read this known elevation,

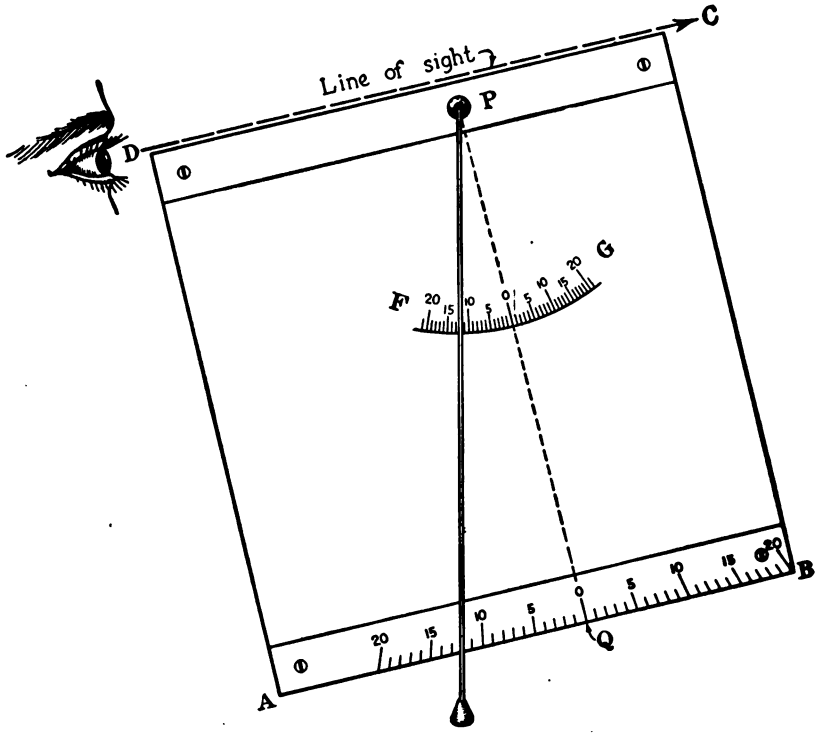

PLATE 27.—Slope Board.

at which times its accumulated error and rate of error since the start, may be noted, and previous readings corrected accordingly. The instrument should be read upon arrival at and departure from each station, and the *differences of elevation* thus obtained alone should be used, not the *actual readings* of the barometer scale, which may be quite inaccurate. This rule is most important. Under favorable conditions very good results may be obtained.

All of the equipment should be carried so that each item is instantly available as needed, otherwise a great deal of time can be wasted. On the other hand elaborate arrangements should be avoided.

The sketching board is often provided with a water-proof cover to be used in case the sketcher is caught in the rain. The traveling or packing box which holds the board and its tripod, with other accessories, should always be left behind when actually sketching. It is not intended to be carried in such a case.

The instruments, such as compass, clinometer and pace tally, are carried in the pockets, or in leather cases on the belt or slung over the shoulder.

An eraser should be attached to the board by a string. (It may be used as the plumb line of the slope board.) The alidade, pencils and pins are carried in the left breast pocket of blouse or shirt, or better in a case made especially to hold them.

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This is much like a toilet case, with a compartment for each article, and is pinned in a convenient position on the sketcher's chest. These cases, in a very convenient form, are sold by the Army Service Schools at Fort Leavenworth, Kans. Any person can easily make one for himself. As affecting the ease and rapidity of sketching and saving the " nerves " of the sketcher, they are very useful.

Range finders. A number of small, portable instruments for the determination of range or distance have been devised, primarily for the use of artillery and infantry in battle. They are comparatively little used by the sketcher. They would be of special value only for place sketching.

Field glasses. A good pair of field glasses, of at least 6 power, is of very great assistance to the sketcher, in increasing the range of his vision and the amount of

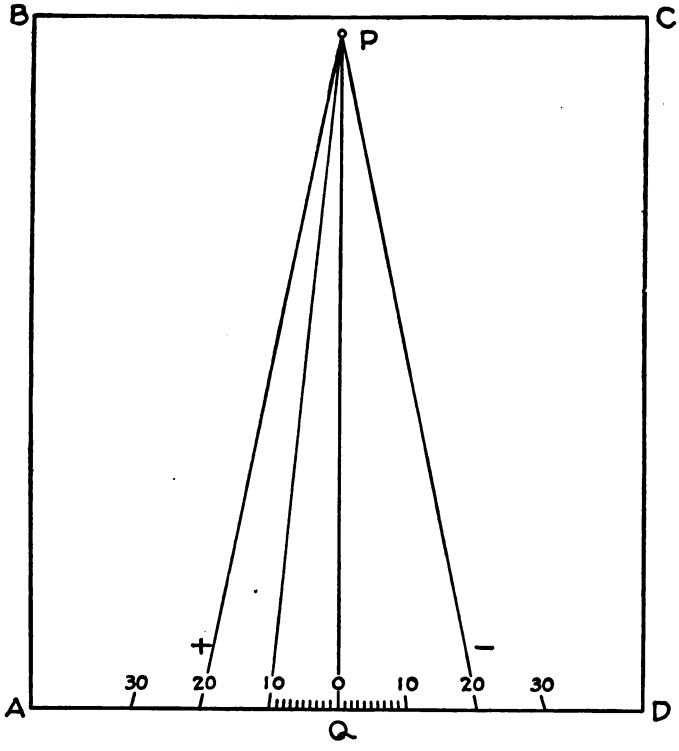

PLATE 28.—Construction of a Slope Board.

detail he can see. They are especially useful in picking out prominent points for sights, and in later identifying such points, also in outpost and place sketching. The glasses are often graduated so that horizontal and vertical angles may be read, usually in mils.[1]

Paper, pencils and miscellaneous equipment of the sketcher. Any kind of paper may be used for sketching. That usually employed is a thin, tough, translucent material, commonly known as tracing paper or vellum. It has the advantage of translucency, which permits details to be traced from another sheet, and also allows blue prints to be made direct from the completed sketch. Blue prints may be made from ordinary paper (if not too heavy) by oiling it, banana oil being best. The results are always unsatisfactory—tracing paper should be used for sketches. For sketching in the rain or snow sheets of celluloid are provided. They are perfectly water proof, as well as translucent.

[1] A mil is a circular arc equal to 1/1000 of the radius of the circle. It is accordingly approximately 1/10 of 1%. To simplify calculations a mil is taken as 1/6400 of a circumference.

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Pencils are largely a matter of personal taste, but there are certain limits as to hardness and softness that should not be exceeded. Lines made with a very hard pencil are illegible. A very hard pencil also cuts or tears the paper. Those made with a very soft pencil are easily blurred and smeared. Generally nothing harder than a 4H should be used even for direction lines which do not appear on the completed sketch. A softer pencil may be used for details where sharp definition is not of importance. Nothing softer than No. 2 or HB should be allowed. An H, 2H or a No. 3 pencil will be found satisfactory for general purposes by the average sketcher. Colored pencils are seldom employed in sketching, but they sometimes serve to make a sketch much clearer and more readable than it would otherwise be. The colors, of course, cannot be reproduced in blue prints.

An ordinary soft pencil eraser (the "ruby" eraser is a good one) should be attached to the sketching board by a string. A "sponge" eraser, for cleaning off large areas, may be carried in the pocket.

The sketcher should carry with him a few thumb tacks and a number of large, stout pins (1½ to 2 inches long) with beaded heads.

Notes.

The methods of orientation discussed in this lesson should be demonstrated to the students, and if time be available they may be allowed to make the determinations themselves.

In connection with the examination of the instruments employed in sketching, the instructor should first demonstrate to the students on the ground, how all the fundamental operations of sketching may be performed without either compass or clinometer. This is important in order to impress on their minds the fact that these instruments are merely accessories which facilitate these operations, but are not essential thereto.

Each of the instruments listed should now be displayed to the class and their methods of operation explained. The students may be required to construct their own slope boards, and cases for carrying alidade and pencils.

Exercises in logical contouring should be continued, as well as practice in drawing and lettering.

Instructors are cautioned to make certain in advance of the course that all necessary instruments and equipment are available.

EIGHTH LESSON.

FUNDAMENTAL OPERATIONS OF SKETCHING.

The fundamental operations of surveying, and of sketching, which is a form of surveying, consist in determining the *direction, distance* and *elevation* of one point of the terrain with reference to other points whose positions are known. These operations are performed with the simple instruments and by the various methods described in this course.

While the student must learn to perform these operations first with accuracy and later also with speed, this facility alone will by no means qualify him to make a sketch. It is of still greater importance that he should fully understand what data or information he needs to make a satisfactory sketch, and how to proceed systematically and swiftly to obtain this information. And he must also fully understand what he does *not* need, that he may avoid waste of time, and confusion.

Horizontal Location.

By geometry the horizontal position of a point is fixed by:

(a) Its direction and distance from a known point.
(b) Its direction from each of two known points.
(c) Its distance from each of two known points.

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The methods of practically applying these principles of geometry to the location of points by plane-table surveying or sketching, are known as, *intersection, traverse, resection* and *offset.*

Horizontal angles are never measured in sketching. The sketching board is oriented, as described in the course in Map Reading, and the lines on the map or sketch are drawn parallel to the lines on the ground which they represent.

Within the limits of a military sketch the curvature of the earth may be disregarded, and the datum of the survey considered as a horizontal plane.

Preliminary to all the operations which are hereinafter discussed, the sketching board should be set up over the point from which observations are taken, and there leveled and oriented. It is not necessary that these operations be executed with great precision. If the board is within a foot or so of the exact point this will suffice. It may be leveled by eye and oriented as closely as this can be done with an ordinary compass, or by a backsight on some point whose position is known and plotted.

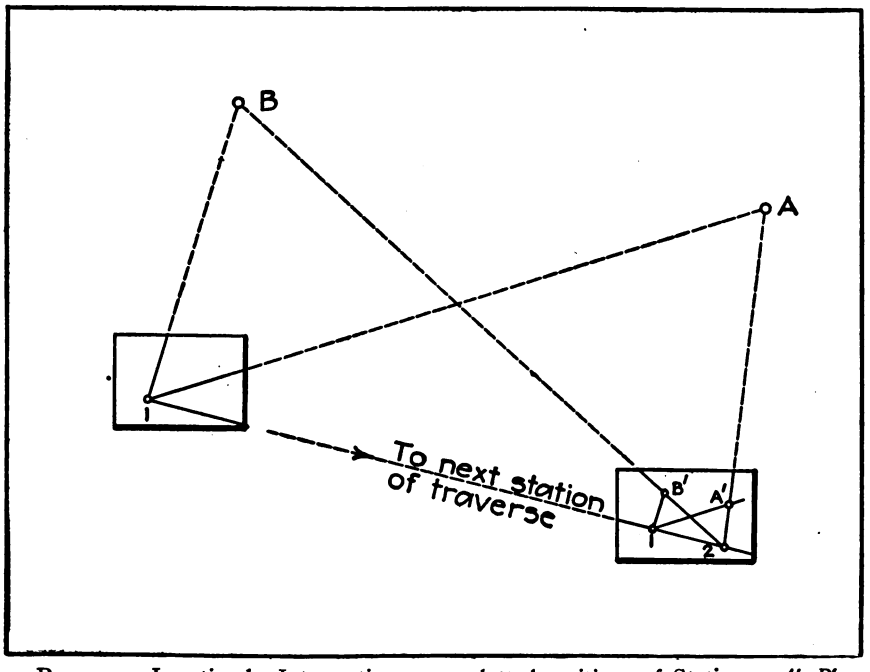

PLATE 29.—Location by Intersection. 1, 2, plotted positions of Stations. *A', B',* plotted positions of *A* and *B.*

Intersection.

Having set up, leveled and oriented the board at the point of observation, stick a stout pin in the position of the point on the sketch. Lay the alidade with either lower edge against the pin, sight along the upper edge; and rotate the alidade about the pin until the distant point to be located is seen in line with the upper edge. Draw a line through the pin, along the edge of the alidade. Prolong the line to the edge of the map, and write on it the name or a description of the object sighted. Or number the line and put a description of the object after the same number in a note-book or on the edge of the sketch. This line is known as a *ray.* Draw rays for all objects whose location is desired. While drawing rays to these important points it is well to make certain, at intervals, that the orientation of the board has not been disturbed.

Now proceed to a second known station or point and by the same process draw rays to *the same* objects. The intersections of these rays will be the map positions of the objects. (Plate 29.) Do not get the rays to different objects confused.

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The angles of intersection of the rays should be as nearly 90° as possible, and never less than 30°.

The locations may be checked or verified by a third ray to each object from a third known point. It should pass through the intersection of the other two. If it does not, an error or a mistake has been made.

Traverse.

The board being properly set up at the point of beginning, draw a ray in the direction of the next station on the route of the traverse. Now proceed to the next station, measuring its distance by pacing (by horse, wagon or automobile). Scale off the distance as ascertained, along the ray from the point of beginning. This locates the second point. Set up the board at this point, orient it by compass and check the compass orientation by a backsight on the point of beginning. Proceed in like manner to locate each successive point.

The traverse may be conducted more rapidly by occupying alternate or odd numbered stations only, where this is practicable. Having drawn a ray from *A* towards *B*, pace the distance to *B*, and locate its position. Without setting up the board at *B*, continue to *C*, pacing the distance *BC*. Set up at *C*, orient by compass. Stick a pin in the map position of *B*, place the alidade against it, and backsight on *B*. Draw the ray *BC*, and lay off on it the distance from *B* to *C* as determined by pacing. *C* is thus located.

It is very desirable that the sights be taken on well-defined objects, such as a fence corner, telegraph pole, tree, building, etc., especially when the course is a short one. Where no such objects are available the sketcher may sight on the middle of the road which he is traveling. Short sights are to be avoided. It is much better to have a traverse consisting of a few long courses than a great many short ones. Accordingly select a point as far ahead as practicable for the next station. This will usually be at a locality where there is a marked change of direction in the line of the traverse.

The count of strides, or the pace-tally, if one is used, should be set back to zero only at the stations of the traverse. The number of paces to intermediate points of importance should be noted, but on resuming the count the sketcher begins where he left off and not at zero. The forward station of the traverse is then located by scaling off the *total* distance from the last station, and not by adding together a number of short stretches.

It is always desirable that a traverse be a closed circuit, that is, that it finish at the same point at which it started, or at least at some point whose position has been accurately located from a previous traverse. This affords a check or proof of the accuracy of the work.

Error of closure. When he has plotted his last course to his point of beginning (Plate 30), the sketcher will invariably find that this point as determined by the last sight and measurement, fails to coincide with its original position, as it should do if the traverse were absolutely accurate. The distance between the two positions of the point of beginning is known as the *error of closure* of the traverse. If it does not exceed about 5% of the total circuit of the traverse the work may be regarded as satisfactory. If it is much greater than this some serious mistake has been made, either in orienting the board or pacing. In case of a large discrepancy it may, if the traverse is an important primary one and the mistake cannot be found, be necessary to do the work over again.

Adjusting the Traverse.

If the error of closure is not excessive the traverse should next be adjusted to eliminate the error by distributing it to the various courses. In the absence of any knowledge as to just where the error has occurred, it is distributed to the courses approximately in proportion to their lengths. In military sketching it is unnecessary that this be done with "hair splitting" accuracy. For example if one course has a length of 325 strides and another 146 strides, the first may be taken as double the

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second for the purpose of distributing the error. The correction is made approximately, in a graphical manner as follows: In Plate 30 *Abcdea* is the traverse as actually run. The point *a* should coincide with the point *A*, which it does not, *aA* being the error of closure. Draw the line *aA*. Through each station of the traverse (*edcb*) draw lines parallel to *aA*, and *in the same direction*, that is in the direction from *a* towards *A*. On each of these lines (*eE*, *dD*, etc.), a part of the error *aA* is eliminated, about proportional to the length of the traverse *from the beginning* up to that point. Thus in the case shown, let us suppose that the *approximate* proportional lengths of the courses of the traverse are as follows: $Ab, \frac{2}{8}$; $bc, \frac{2}{8}$; $cd, \frac{1}{8}$; $de, \frac{2}{8}$; $ea, \frac{1}{8}$. That is to say *Ab* is approximately $\frac{2}{8}$ of the length of the entire traverse, $Ab+bc$ is $\frac{4}{8}$ the entire length, $Ab+bc+cd$ is $\frac{2}{8}+\frac{2}{8}+\frac{1}{8}=\frac{5}{8}$ of the entire traverse, etc. Hence, lay off on the line *bB* the distance *bB* equal to about $\frac{2}{8}$ of the total error, *aA*. Similarily lay off *cC* equal to $\frac{2}{8}+\frac{2}{8}=\frac{4}{8}$ of *aA*. *dD* is $\frac{5}{8}$ and *eE* $\frac{7}{8}$ of *aA*. Connect the points thus determined, and connect the last one with *A*. *ABCDEA* is the adjusted traverse, in which the error of closure has been distributed amongst the courses, approximately in proportion to their lengths.

If the traverse is long and the error small it may be distributed over the last few courses only, instead of the entire traverse. Care must be taken that this does not

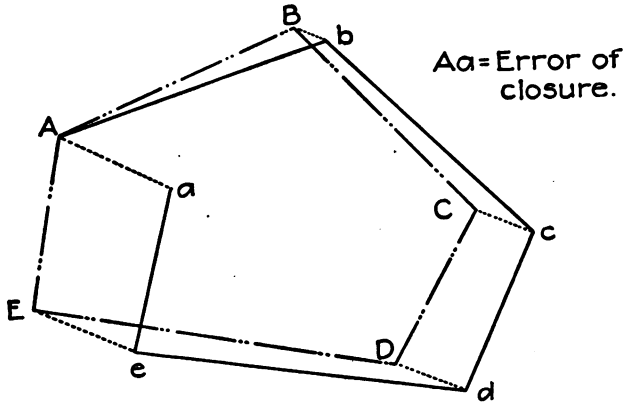

PLATE 30.—Adjusting a Traverse.

result in any marked change in the angle between two adjacent courses, as this might be misleading. Errors in sketching are permissible so long as the sketch fulfills its purpose, but they should be gentle ones, so that the user of the sketch will not be startled and lose confidence in it when he encounters them.

Errors in level or elevation are adjusted in the same manner as errors in distance.

As the sketcher proceeds with his traverse he performs other necessary operations at the same time, such as intersection, determination of elevations, and the filling in of any details for which he has the necessary data.

Traversing is a most important operation in sketching, and should be performed with great care. The primary traverse of the sketch forms the control and base line thereof, on the accuracy of which all other operations of the sketcher absolutely depend. If the traverse be in error all intersections taken from it will be still more in error, and the sketch as a whole badly out of true. No amount of care in filling in details can compensate for a carelessly executed traverse.

Resection.

Resection is the reverse of intersection, or the location of an unknown point at which the sketcher finds himself, by sighting on two or more known points. (Plate 31.)

Suppose the sketcher to be at a point *P*, whose position is not previously known, but from which two known distant points, *R* and *S*, are visible. The board is set

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up and oriented by compass. Now stick pins in the map positions of R and S, sight on each, as heretofore described and draw the rays from r and s. Their intersection will be the map position of the point P, or place at which the sketcher stands.

A special case of resection, using three points, when orientation by compass is impracticable, is described in the course in Map Reading.

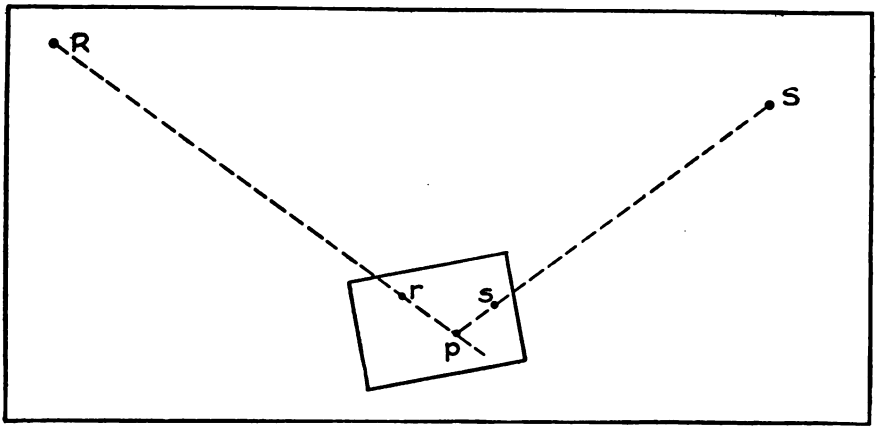

PLATE 31.—Location by Resection.
r and s are the plotted positions of R and S. The point p is located by resection on R and S, its plotted position being P.

Resection is especially useful in determining the position of some point which the sketcher desires to occupy, but which because of the lack of any prominent landmark, has not been fixed by intersection.

Offset.

Offset is a method of determining the location of points at a short distance right or left from the line of a traverse. It is especially useful for putting in isolated

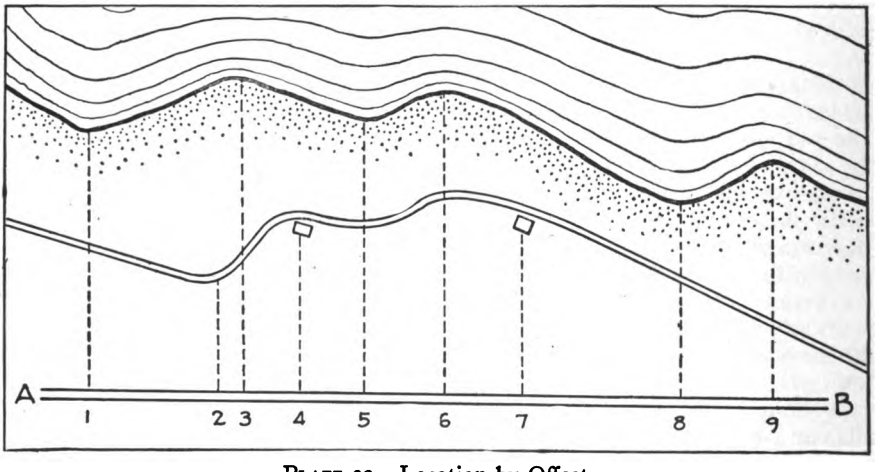

PLATE 32.—Location by Offset.

details, or an irregular line which cannot be readily traversed, such as the shore of a lake, etc.

In Plate 32, a sketcher traversing along the road AB wishes to put in the shore of the lake, and the houses and road between AB and the shore. This he does by offsets, 1, 2, 3, 4, etc., to the critical points of the road and shore. Having left A

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the sketcher notes the number of strides which bring the first angle in the shore line, directly opposite his position (at right angles to the line AB). This he determines by eye, or by using an optical square if he has one. He draws the offset line 1 perpendicular to AB. If the distance is not great, or if the location is not of great importance, he may estimate this distance. Otherwise he will leave his traverse and pace it. The distance to the turn in the road opposite 2, being very short, may be estimated. In continuing along AB from each offset the sketcher takes up the count of his strides where he left off, keeping the total count from A.

If the distance makes it necessary to pace many of these offsets it would be more economical of time and give better results to run a secondary traverse along the shore. For details which are close at hand, whose distance out may be closely estimated by a skilful sketcher, this method is very useful. It is commonly used for picking up details near at hand, and is especially applicable to route sketching when time does not allow the sketcher to leave the route. It is of course essential that the sketcher be fairly accurate in the estimation of distances.

Minor details at short distances are most readily filled in by offset from the line of a traverse. The method gives rapid and quite accurate results if the sketcher is well practiced in estimating short distances. If an optical square and pacing be used the method is sufficiently accurate for control.

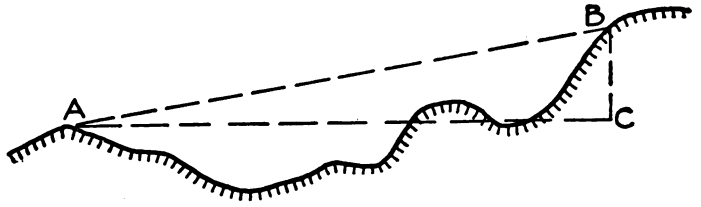

PLATE 33.—Distance and Elevation.

Elevation.

The elevation of any point with respect to any other point is determined from the distance between them and the slope of the line of sight from one to the other, regardless of the actual contour of the ground between the two points. Thus in Plate 33 the elevation (BC) of B above A is fixed by the horizontal distance AC and the slope of the line of sight, AB, and has nothing to do with the hills and valleys between A and B. If the distance AC be 2600 feet and the slope of AB 8%, the height of B above A is 8% of 2600, or 208 feet.

When slopes are measured in degrees it is necessary to change degrees to per cent in order to calculate differences of elevation, and the method by percentage is hence more convenient.

Many clinometers and slope boards used in military sketching are graduated in degrees, and in such cases differences of elevation are determined graphically by means of what is called a slope scale, discussed in the following lesson.

Notes.

Ability to perform with speed and accuracy the fundamental operations of sketching, discussed in this and the previous lesson, is a necessary foundation for the military sketcher. No special terrain is required for this preliminary instruction most of which can be carried on to advantage on the college campus, although of course a more diversified terrain is desirable. During inclement weather it is even possible to give some of the instruction indoors, in a large room, preferably an armory. A complete sketch should not be undertaken until these operations can be performed with facility.

The students should be required to assume an imaginary traverse with an error of closure, and adjust the traverse as herein described.

In the Introduction to the course in Military Sketching, also in the tenth lesson, following, will be found some suggestions as to the conduct of the course. They may

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assist in laying out a progressive course of practical instruction. The exact program will depend on the conditions at each institution and cannot be rigidly prescribed to meet the needs of all. The important thing is *to have a definite program* of practical work, based upon the time and facilities available, and logically progressive. If the practical work is conducted in hap-hazard fashion, each day's program being made up on the spur of the moment, the time spent on the course will be in great measure wasted, some instruction will be uselessly repeated, and some essential points entirely overlooked.

The following are some of the important items of preliminary instruction which should be taught practically in about the order given:

Logical contouring.

Drawing and lettering of sketches. Conventional signs.

Making scales of paces.

Orientation by various methods.

Use of the available instruments in the fundamental operations of sketching, intersection, traverse, measurement of slopes, etc.

Making slope scales.

Estimation of distance, etc.

The instructor must of course make certain that the necessary *equipment* for carrying out his program is, or will be available.

NINTH LESSON.

Slope Scale.

A *slope scale* is a device giving for any map scale (or representative fraction), and for any assumed vertical or contour interval, the horizontal distance between adjacent contours on the map, corresponding to any given degree (or per cent) of slope.

Let us assume a scale of 6 inches = 1 mile, and a vertical interval of 10 feet between contours, these being the scale and vertical interval usually employed for military position sketches in the American Army. A slope of 1° equals 1.75%, or a rise of 1.75 feet in each 100 feet of horizontal distance. A rise of 10 feet would therefore correspond to a horizontal distance of $10 \div 1.75 \times 100 = 571$ feet (about). On a scale of 6 inches = 1 mile (R. F. = 1/10,560) this would equal about 0.65 inch on the map, which is the horizontal distance between adjacent 10 foot contours on a uniform slope of 1°, or the horizontal distance for a rise of 10 feet on such a slope.

We may now construct a slope scale (*A*, Plate 34) with divisions of 0.65 inch graduated 10, 20, 30, etc., with an extension reading to 2 feet. This will be the slope scale for a 1° slope on a map having a scale of 6 inches = 1 mile. Suppose the slope from *A* and *B* to be 1°. Plot *A* and *B* on the map. Lay the slope scale on the line *AB*. The distance *AB* as measured by this scale, will be the difference of elevation of the two points in feet. If the slope of *AB* is 2°, the difference of elevation would be twice that indicated by the scale, for ½° half that indicated, etc. For sketching purposes slopes are seldom read closer than half a degree.

The horizontal distance between contours is approximately inversely proportional to the degree of slope (this is not true for very steep slopes). Hence, for a 2° slope the horizontal distance (on the 6-inch map) would be .65 inch ÷ 2, for a 2½° slope .65 ÷ 2½, etc. Plate 34 (*B*) is a scale giving the horizontal distances for all degrees of slope from ½° to 10°, for a map on a scale of 6″ = 1 mile, with a contour interval of 10 feet. Such a scale is used for spacing contour points on a sketch, without the necessity of making calculations. The scale may be pasted on one of the edges of the sketcher's alidade.

While contour points on any uniform slope may be laid off with this scale (*B*, Plate 34), it is much more convenient and accurate to have a separate and continuous scale for each slope. As this would require a great number of scales, they are usually combined as much as possibile, to occupy not over 3 or 4 of the 6 edges of the alidade. Slope scales which are even multiples of each other are readily combined, for

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example ½°—1°—2°, or 2½°—5°, or 3½°—7°, etc., Plate 34 *C* represents such a combined scale. The figures on the graduations are not really necessary, as one division is understood to be the distance between adjacent contours for a 1° slope.

Plate 35 represents a complete slope scale for use in sketching. These scales may also be pasted on the edges of the alidade.

Another useful form of scale which the sketcher may make for himself is a *scale of differences, i. e.,* one showing the rise (or fall) in feet, for any horizontal distance, corresponding to a 1° (or 1%) slope on maps of various scales. For a 2° slope the rise is multiplied by 2, etc.

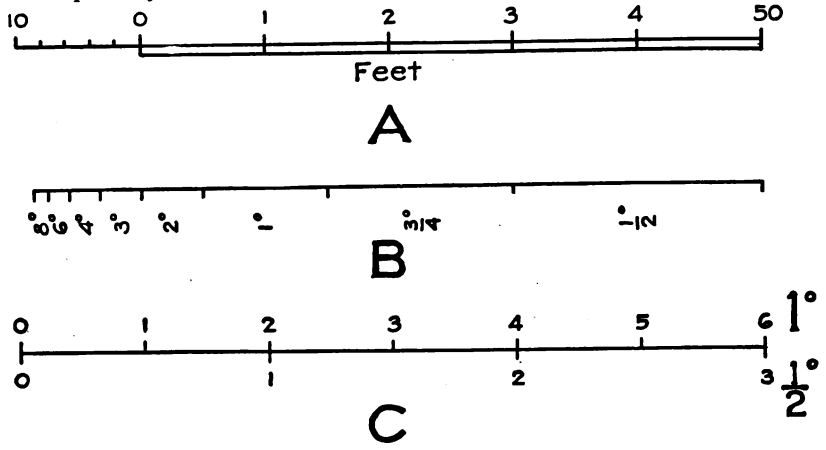

PLATE 34.—Slope Scales.

Locating the Contour Points on a Slope.

Suppose *A* and *B*, Plate 36, to be two adjacent critical points of the terrain, as for instance on the crest line of a spur. The elevation of *A* is 175 feet and the ground slopes uniformly on a 2° grade from *A* down to *B*, whose elevation is not known. From the scale (Plate 34 *B*) take off with a slip of paper a number of intervals corresponding to a 2° slope (or use the 2° continuous slope scale as in Plate 35, if

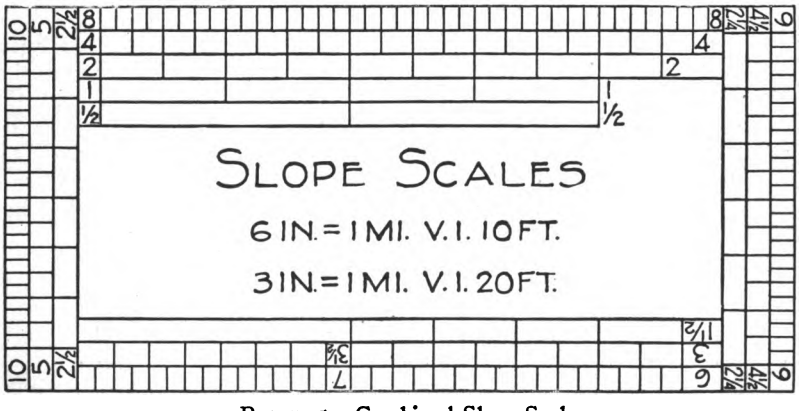

PLATE 35.—Combined Slope Scales.

there be one). Lay the strip along the line *AB* so that *A* falls half way between two of the division lines, corresponding to its elevation half way between two 10 foot contours. Then mark each point of division, continuing to *B*. These will be the points where the contours cross the crest. Incidentally the elevation of *B* is found to be about 273 feet.

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To obtain the H. D. for any intermediate slope, as $3\frac{1}{2}°$, take half the sum of the H. D. for 3° and 4°.

If the slope between *A* and *B* is not uniform the contour points cannot, of course, be plotted at equal intervals as just described. But the application of the proper slope scale will give *the number of contour intervals* between the two points, and the elevation of *B*. The contours should be adjusted to show the facts. When the slope is read in per cent the difference of elevation is found by multiplying the horizontal distance between the two points by the slope, which gives a more accurate determination than the slope scale inasmuch as the clinometer may be read as closely as desired.

In reading the slope a definite and readily identified point should be selected to sight upon. This may be the root of a tree, the base of a large stone, foot of a telegraph pole or foundation of a building, etc.—always a point on the ground if possible. The clinometer gives the slope from the observer's eye to the point sighted. The difference in elevation having been calculated, it should be corrected for the height of the observer's eye above the ground. If practicable the sight may be taken in a prone position, which enables the sketcher to hold his clinometer more steadily and take a closer reading.

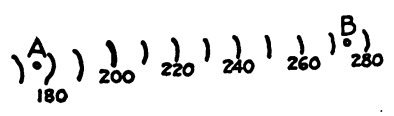

PLATE 36.—Spacing Contour Points With a Slope Scale.

The elevations of important points should be determined by the clinometer. For less important points vertical heights or slopes may be estimated.

Formula for slope scale. The following formula may be used for calculating the horizontal distances between contours on any map, with any scale, any vertical interval and for any degree of slope.

$$\frac{688 \times \text{R. F.} \times \text{V. I.}}{\text{A}} = \text{H. D.}$$

In this equation:

R. F. equals representaive fraction of the map.
V. I. equals vertical interval in feet.
A equals angle of slope in degrees.
H. D. equals horizontal distance between contours on the map, in inches.

The Normal System.

It will be noted from this equation that if we double the V. I. and halve the R. F. at the same time, the H. D. remains unchanged. Thus for the 6-inch map the R. F. is 1/10,560 and the V. I. is 10 feet. If we assume a 3-inch map (whose R. F. is $1/10{,}560 \div 2 = 1/2120$) with a V. I. of 20 feet, the H. D. for all slopes will be the same as on the 6-inch map, and the same slope scales could be used. The same would be true for a map on a scale of 1 inch equals 1 mile with a V. I. of 60 feet.

The scales and vertical intervals for the topographical maps and sketches commonly employed for tactical purposes in our army are as follows:

1 inch equals 1 mile, vertical interval 60 feet.
3 inches equal 1 mile, vertical interval 20 feet.
6 inches equal 1 mile, vertical interval 10 feet.
12 inches equal 1 mile, vertical interval 5 feet.

These maps constitute what is called the *normal system,* in which the vertical interval varies inversely as the scale, and the horizontal distance between adjacent contours for any given degree of slope is the same for all maps of the system. This has the advantage that the eye of the sketcher or map reader learns to recognize a certain contour spacing as indicating always the same slope, and that the same slope scales may be used in making sketches on any scale of the normal system.

Slopes in degrees and in per cent. The method of reading slopes, calculating elevations and plotting contours by grades expressed in percentage instead of degrees, is simpler and easier. But the method by degrees has heretofore been more

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commonly employed. Slope scales for per cent are constructed in exactly the same manner as those for degrees. Thus for a 1 per cent slope the horizontal distance (on the ground) between two adjacent 10 foot contours is 1000 feet, which on the 6-inch map is about 1.15 inches. For a 2% slope the H. D. is 0.6 inch, and so on. This system has the further advantage that the H. D. for a 20% slope is 1/20 that for a 1% slope, which is not strictly true in the case of slopes measured in degrees. The advantage of the normal system will apply as well if slopes are measured in per cent as if they are measured in degrees.

Estimation of Distances, Elevations, etc.

Important measurements in the control of a sketch should not be guessed at. But it is manifestly out of the question to actually measure all distances and elevations. When the control of the sketch has been plotted, most of the details are filled in by estimation within the comparatively limited distances between the located points.

The ability to estimate distances and elevations comes only from practice. A skilled man can estimate short distances with an error not exceeding 10%, which is sufficiently accurate for the location of all minor details.

Distances. Estimations of distance in position sketching should generally be limited to not over 200 to 300 yards, depending on the skill of the sketcher. In route, place and outpost sketching, it will frequently be necessary to estimate greater distances, 400 to 500 yards and even more. The sketcher should be able both to estimate his distance from a visible point and the distance between two points other than his own location. The units of distance generally used in estimating are 10 yards for short distances and 100 yards for long distances and the sketcher should have these distances well fixed in his mind. For beginners, as an aid in estimating, it is often well to pace off and mark a short distance (10 to 20 paces), to be used for comparison with greater distances to be estimated. Distances are estimated chiefly by the appearance of familiar objects as seen at a distance; a man, a horse, a wagon, an ordinary house, a telegraph pole, etc. If a field glass graduated to read mils is available, it will be of great assistance. Thus if the height of a man as seen through the glass is 4 mils, the distance will be $1000/4 \times 5.75$ feet equals 1440 feet. A line of telegraph poles, which are usually spaced 35 to the mile (50 yards apart), is useful as a guide in estimating. It will be good practice for the student to estimate all distances which he has to pace, and verify his estimates, noting the tendency of his errors, or his "personal equation," that is whether he tends to over- or under-estimate. Estimations of distance will usually be limited to "side shots." Distances along the traverse should always be measured.

Objects seem nearer than they really are:

When in a bright light.

When the object is in strong contrast with its surroundings (especially the background) in color or shade.

When seen over water, snow, or any uniform, flat surface.

When viewed from above.

In a clear atmosphere, especially in high altitudes.

Every feature of the terrain should be utilized to assist in estimating distances. The sketcher should by practice accustom his eye to the appearance of familiar objects as seen at various distances.

Elevations. The unit for estimating vertical heights is one contour interval, which is 10 feet for a 6-inch (equals 1 mile) map. The greatest difficulty in estimating elevations is that of determining what points are on the same level as the observer. Facility in doing this can be acquired only by practice. The student should select points which he believes to be on a level with his eye and check the accuracy of his judgment with his clinometer (zero reading). Practice may be had indoors by holding the hand extended at the supposed height of the eye, and checking by noting the points on the wall seen over the tops of the fingers. The height of distant points is estimated by their number of contour intervals above or below an adjacent point on a level with the sketcher's eye. The heights of familiar objects, such as a telegraph

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pole, a house, etc., in the locality of the point whose elevation is desired, may be used as units of measure.

Slopes. Slopes are estimated by mental comparison with known slopes. Practice will enable the estimate to be made with a fair degree of accuracy. The sketcher should make frequent estimates of slopes, and verify them by clinometer readings.

The student, in the beginning, should measure all distances, elevations and slopes, after having in each case made an estimate. He may later increase his speed by frequent estimates as soon as he has satisfied himself of his ability to make such estimates within the allowable limit of error (about 10% either way).

Errors and Mistakes.

It is well at this point to note the difference between *errors* and *mistakes,* so often referred to in this course. An error is a variation from the truth, inherent in the instruments and methods employed or the personality of the sketcher (personal equation). It cannot be avoided, but can only be held to the smallest possible value. A mistake is a fault due to carelessness or inattention on the part of the sketcher. Thus, if a sketcher reads a certain slope with his clinometer, as 8% when actually it is 8.12%, he has made an error. But the error is unavoidable, because the clinometer will not read such small angles as 0.12%. Such errors are inherent in the clinometers employed in sketching and must be accepted. But if the sketcher records the slope as *minus* 8% (downhill), when it should have been *plus* 8% (uphill), he has made a very serious and inexcusable *mistake.*

Method of Procedure in Sketching an Area.

The beginner's difficulty in sketching is due not so much to his lack of skill in the use of his instruments, as to his lack of knowledge of the fundamental principles of sketching, and his failure to proceed systematically to obtain the data he needs, without wasting his time on non-essentials.

From his practice in logical contouring the student should have learned what are the master lines and critical points which he needs. He now proceeds systematically and without waste of effort, to obtain these points.

As the sketcher develops skill he will learn for himself many "short cuts" in obtaining the necessary data. But these should not be attempted too early.

There are a number of different methods of procedure which will produce the desired results, each of which has its advocates. But while one sketcher may follow a somewhat different program from another, there is no room for any wide departure. The following general method is recommended as effective and systematic.

The sketcher will first run a primary traverse around the area to be sketched, returning to his point of beginning. This traverse should be near but not necessarily *on* the boundary lines of the area. If there be roads, railroads or trails conveniently located, these should be followed, as easier routes than cross country, and such features must be placed on the sketch in any event. In any case it is desirable that, so far as practicable, the traverse be run on commanding (high) ground, affording a good view of the country. All measurements should be made with care, and the traverse adjusted upon its completion. As this traverse forms the *base line* for the entire sketch, it is very important that it be carefully measured and located, and that no mistakes be made. For if the traverse is poor the entire sketch will be very inaccurate, no matter how carefully the subsequent operations are performed. If the primary traverse is run on a road the measurements are more apt to be accurate than if it is run across country, and mistakes are more easily avoided.

In running this traverse the sketcher should locate:

a. Every drainage line encountered, both those which cross the traverse, and those which run near enough to be located without going too far off the sketcher's route. As much of these lines should be located at this time as is practicable. Not all of them, in fact only a few, will be flowing. Most gulleys carry water only during a heavy rain, but they are nevertheless master lines of the terrain. In every case

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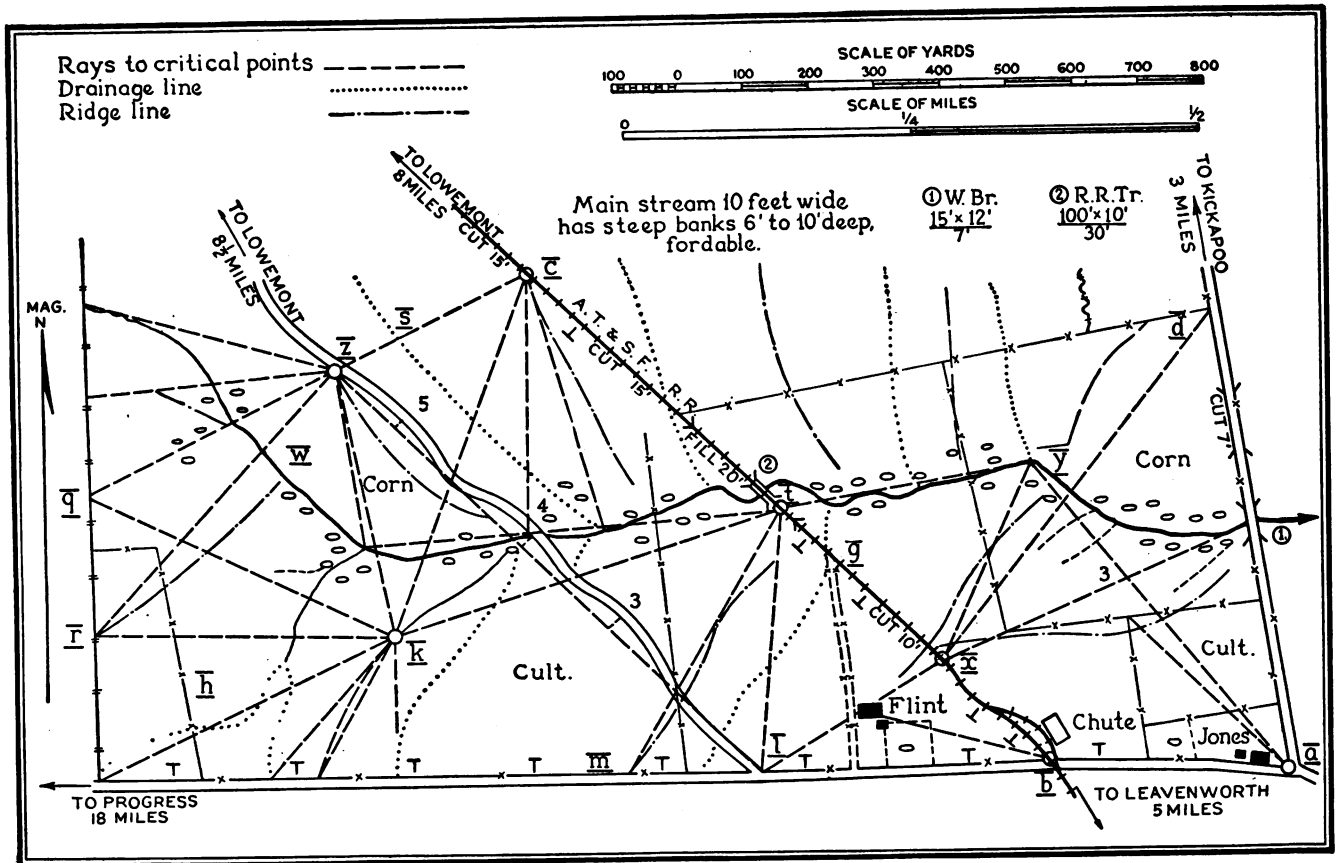

PLATE 37.—Horizontal Control of Position Sketch.

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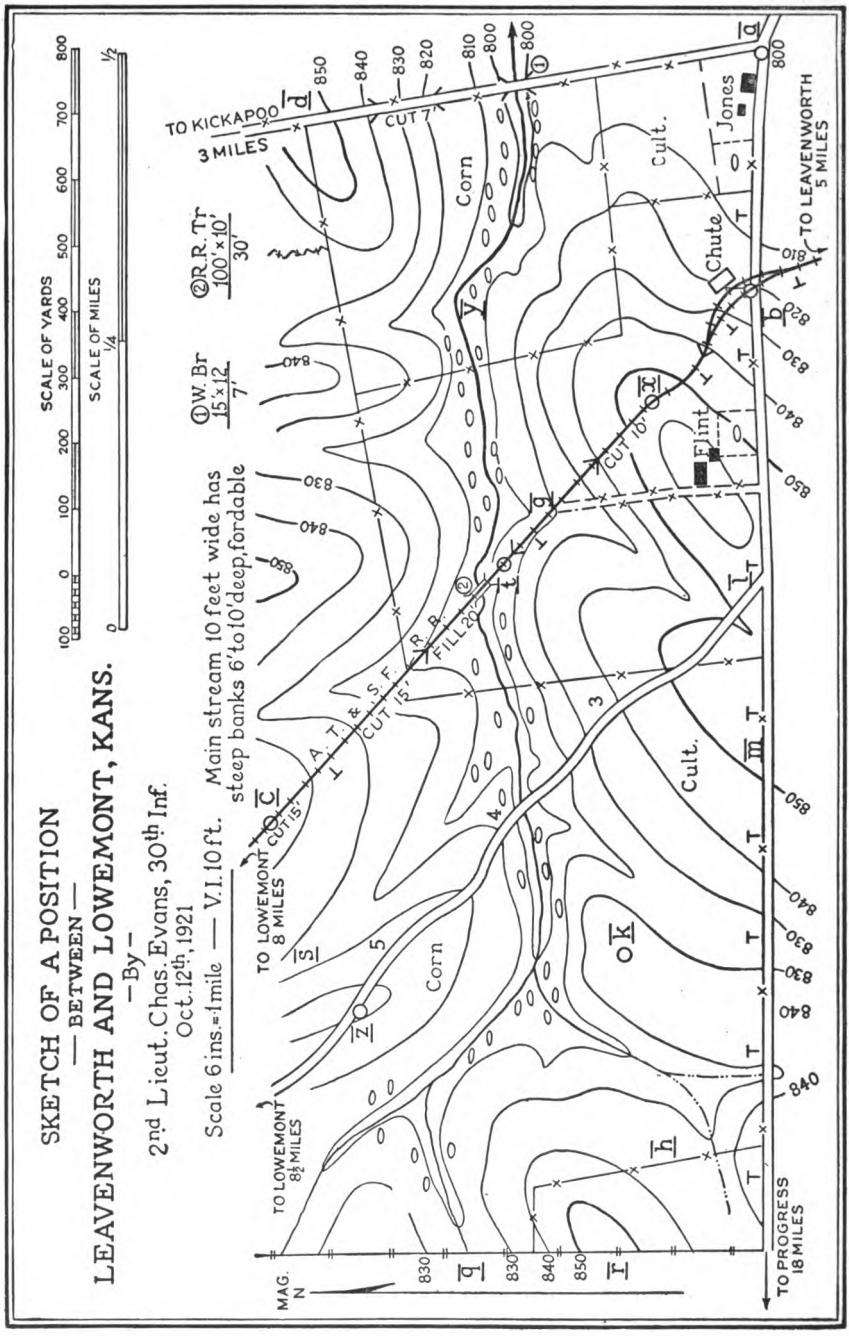

PLATE 38.—Completed Position Sketch.

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note the direction in which the stream flows, or would flow if there were any water in it.

b. All hill tops and ridge lines on or close to the traverse.

c. All features of the terrain other than topography, which are close enough to the sketcher's route to be properly located. This will include buildings, fences, roads and railroads, etc. These features must be included in the sketch, and they will be useful later for identification.

d. Prominent landmarks at a distance from the sketcher's route, both within or occasionally outside the area to be sketched, which will be useful later for locating or checking locations by resection. These locations are made by intersections from suitable points along the traverse. The intersection of two lines of sight (rays) determines a point, but the accuracy of the observations may be checked by a third ray which should pass through the point of intersection of the first two.

The rays to various objects should be numbered for identification, or prolonged to the edge of the sheet, and the name or description of the object written on the ray.

e. For all points which are *critical* to the topography the *elevation* as well as the horizontal positions should be determined. If the point is for horizontal reference only, that is not critical as to elevation, its height of course need not be determined. Such points would be houses, fence corners, road junctions or turns not involving a change of slope, etc.

Thus far the beginner, at least, should have drawn no contours. An experienced sketcher will probably have put in the contours of some of the forms he has encountered. But it is well to be acquainted with the general lay of the country before attempting any extensive contouring. At least the sketcher should have seen enough of his area to know its chief features, especially its main drainage lines.

If one attempts to contour an isolated feature, such as a single hill or ridge, before he has grasped the topography of his area as a whole, he is very apt to have an exaggerated idea of the importance of this feature, and to portray it accordingly. Every hill seems important when we are standing on it.

Having now been around his area the student will have seen much of it, and in particular will have noted all the drainage lines that run into or out of it. If the country is open he will have been able to see into the interior of his area, and perhaps to locate some of the stream junctions and hill tops by intersection from his primary traverse. In such case he will have been able as well to determine the elevations of these critical points.

If the area be a very small one the sketcher may now be ready to put in his contours. But in a larger area, especially if the country is not open to view, a visit to the interior will almost certainly be necessary. The sketcher must know just how the drainage net lies—it is never safe to guess about this—and it is usually impossible to see all the net from the main traverse. So the sketcher must visit the interior of the area and see what is there.

As to the most favorable route to be followed in visiting the interior, this may be determined by the knowledge of his area which the sketcher has gained in making his primary traverse. But if he is undecided as to this, it should be remembered that *any* route will answer if the essential operations are carefully performed. A road is of course to be preferred, if one be found running in the right general direction.

The sketcher may proceed at once to some important point inside the area, which he has previously located by intersection, or he may locate the point by resection when he has arrived. But it will generally be better to run a traverse through the area, connecting with the primary traverse at both ends. If the area be large, or densely wooded, two or more of these secondary traverses may be necessary. Otherwise a single through traverse with short offset or branch traverses here and there, will suffice. The sketcher must be guided by remembering what he is seeking, which is the drainage net with the critical points of the hills and ridges between the stream lines. He must make certain that he has seen all the important features of the topography, and properly located all that he has seen.

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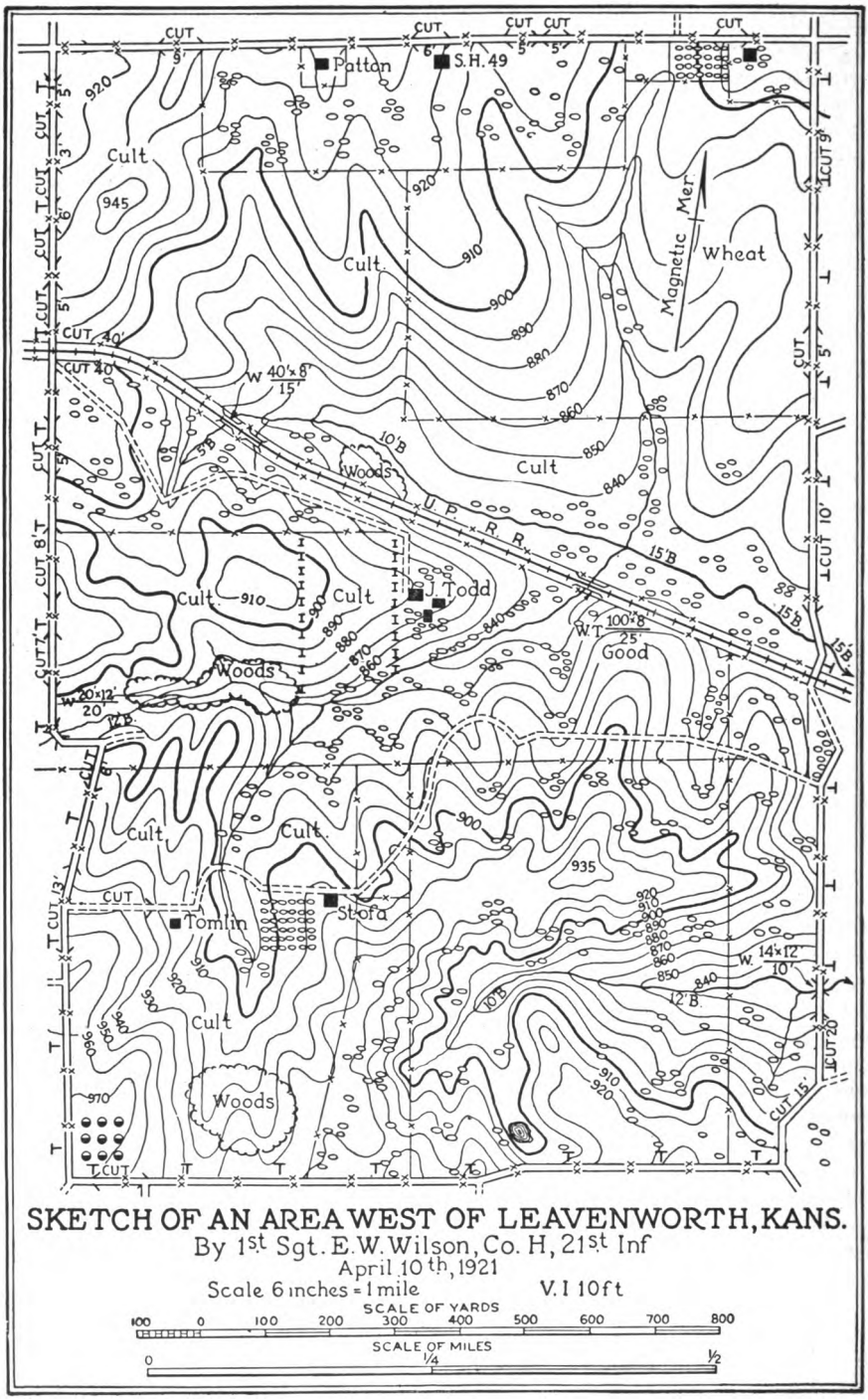

Plate 39.—Position Sketch.

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The result of these operations should be a skeleton of the area, similar to those used in the problems in logical contouring. (Plate 15 *A*.) It may be completed in the same way, and in doing this the student will have impressed upon his mind in the most forcible manner just how far he has failed to gather necessary and important data for a complete sketch.

The expert sketcher will perform his traverse and make his locations with such accuracy that only slight adjustments will be necessary. His faculties of observation and his powers of interpreting ground forms, and " sensing " the presence of things he cannot see, will be so highly developed that long before he has seen all of his area he will have a sufficient general knowledge concerning it and enough located critical points to begin putting in the contours. Where he has not sufficient data for this he may sketch in the form lines of the terrain very lightly, and later adjust and complete them when the necessary precise data has been obtained. He may later visit a few commanding points (affording a good view) and there complete his sketch. In other words, the expert sketcher can usually contour as he goes, and complete his sketch without revisiting localities once passed over. He will soon learn by experience the extent to which such procedure is possible.

The beginner who attempts to contour as he goes is certain to find himself in trouble. He should locate his critical points and then complete his sketch as a problem in logical contouring, or in sight of the facts by revisiting the prominent points in the area, completing his work by means of the precise data he has obtained, aided by an actual view of the terrain.

Notes.

The subject of slope scales is a difficult one, and can be made clear only by practical demonstration. The instructor should explain to the students that *between adjacent critical points* the ground is assumed to slope uniformly, and that on any uniform slope the contour points can be placed by means of a slope scale. Actual slope scales as used in sketching should be exhibited and their practical use demonstrated. Such scales can be obtained from the Army Service Schools. The subject is so important that it must be thoroughly understood.

Estimation of heights and distances should be made whenever opportunity affords throughout the course, since the ability to make such estimates to within 10 to 12% of the truth, is essential to the sketcher. It is, of course, of no use to estimate distances unless the estimates are verified. A single day's instruction in estimating will not be sufficient—the exercise should be repeated at intervals during the course.

By this time the students should have received sufficient training in the fundamental operations and in the interpretation of ground forms (including logical contouring) to be ready to attempt an area sketch. In this lesson the program of procedure for an area sketch is given. If it be possible at this stage of the course to combine two or three periods of practical instruction, the instructor should take his students on a " topographical walk " around and through some area, preferably one he has himself sketched. During this walk the program will be practically reviewed, the instructor pointing out the procedure at each point, indicating the data needed, etc. This will be the final step in their instruction, after which the students should make a sketch themselves. This should be done during the college year if possible, but failing this, a better opportunity will be afforded during the summer camp.

Practical Problems.

The following problems pertain to this lesson:

1. Assuming 0.65 inch as the map distance (H. D.) for a slope of 1°, construct slope scales for $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$ degrees.

Solution: It is assumed that for any given map the H. D. for various slopes is inversely proportional to the degree of slope. Thus for a $\frac{1}{2}$° slope the H. D. is twice that for a 1° slope.

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2. Assume any two points as *A* and *B*, having a known distance between them, and known elevations. Assuming a uniform slope between the two points, put in the contour points, using a slope scale. This operation, of course, must be performed in the process of logical contouring, in which the students should have been instructed.

3. The slope from *A* to *B* as read by the clinometer is $2\frac{1}{2}°$, and the distance is 670 feet. What is the difference of elevation of the two points?

Solution: The percentage corresponding to $2\frac{1}{2}°$ (from table in third lesson, p. 27) is 3.5 plus $5.25 \div 2$ equals 4.4% (approx.). Hence, the difference of elevation is 4.4% of 670 or 29.5 feet.

4. Construct a slope scale for a slope of 3° on a map having a scale of 2 inches equal 1 mile, and a contour interval of 15 feet.

Solution: From the formula for slope scale in the lesson we obtain the horizontal map distance in this case (R. F. equals 1 divided by 31,680):

$$\frac{688 \times 15 \times 1 \div 31{,}680}{3} = 0.108 \text{ inches.}$$

The slope scale will be simply the above distance repeated any number of times, the points of division being marked 1, 2, 3, 4, etc., or 15, 30, 45, 60 feet.

Any other slope scale may be constructed from the H. D. determined as above. Thus for 1° slope the H. D. would be $3 \times .108$ equals 0.324 inches, for 4° it would be $\frac{3}{4} \times .108$ equals 0.081 inches.

5. What would be the H. D. for a slope of 8% in the above case?

Solution: If the slope is 8% and the V. I. 15 feet, the corresponding horizontal distance is 15 divided by 0.08 equals 187.5 feet. On the map this distance would be 187.5×12 divided by 31,680 equals 0.071 inches.

6. Is the map referred to in problem 4 on the "Normal system?"

Solution: A map of 1 inch equals 1 mile with a V. I. of 60 feet is on the normal system. If we double the scale we must *halve* the contour interval, that is a map with a scale of 2 inches equal 1 mile, would have a contour interval of 60/2 equal 30 feet, if it were on the normal system. Hence, the map in question is *not* on the normal system.

7. A map on a scale of $1 \div 250{,}000$ has a contour interval of 80 feet. What would be the contour intervals in maps of the following scale in the same normal system?

$1 \div 125{,}000.$
$1 \div 62{,}500.$
$1 \div 31{,}250.$
$1 \div 15{,}625.$

Solution: In any normal system as we double the R. F. we halve the contour interval. Hence, the V. I. for the maps mentioned would be 40, 20, 10 and 5 feet, respectively.

8. Evolve a formula for slope scales in per cent for any map, contour interval or slope.

Solution: The distance on the ground, corresponding to any contour interval and any slope, is equal to the contour interval divided by one hundredth of the slope in per cent. This distance will be in feet. If it be multiplied by 12 to reduce to inches, and then by the R. F. of the map, we have the H. D. on the map, in inches, corresponding to the given scale, contour interval and slope.

Accordingly the formula is:

$$\frac{\text{V. I.} \times 100 \times \text{R. F.} \times 12}{\text{A}} = \text{H. D.}$$

in this equation.

V. I. equals vertical interval in feet.
R. F. equals representative fraction of the map.
A equals slope in per cent.
H. D. equals horizontal distance between contours on the map in inches.

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The students may be given a number of practical problems in the construction and use of slope scales, similar to the preceding.

TENTH LESSON.

Critical Data Required.

The critical data required by the sketcher to complete his sketch may be summed up as follows:

The complete location (horizontal position and elevation) of all stream or drainage lines at the points where they enter or leave the area, or cross the main traverse around the area, at their sources (where these occur within the area), and at every junction of a main and tributary line.

The complete location of the tops of hills and the crests of spurs and ridges, and all points of marked change of slope on the crests or sides of ridges and hills.

The horizontal location of all important and conspicuous landmarks.

All details (other than ground forms) both natural and artificial, which are of military value (this will include most such features).

Useful Hints for Sketchers.

It is not unusual for a beginner in sketching to become "obsessed with the terrain." He sees so many features, all of which appear important because they are close by, that he forgets the caution to seek only the critical points, and wastes most of his available time securing data which is not only useless, but actually confusing. To avoid this it is necessary to adopt a systematic procedure, and rigidly adhere to it.

It is not necessary to set up and orient the board except for important locations, usually only at the main stations of the traverse. When the sketcher passes an object which should be shown on his map such as a building, it is plotted in, but it will seldom be necessary to set up and orient the board for this purpose.

For important sights the board should be oriented either by compass or backsight, and checked by the other method.

Objects of local importance only, and which do not concern the control of the sketch, are frequently located by estimating their direction, distance and elevation. An error in such estimations will affect only the object concerned. But heights and distances which are essential to the general control of the sketch, and on which other locations depend, should not be estimated, but measured as accurately as practicable.

In other words measurements are to be made accurately where accuracy is necessary, and no time is to be wasted in striving for accuracy where it is not needed. An error of 10 or 15 degrees in the bearing of a long course of an important traverse will seriously affect the accuracy of the sketch as a whole. An equal error in the direction to a house a hundred yards from the road will make little if any difference in the *military* value of the sketch.

Having arrived at a station of the traverse the sketcher sets up his board, scales off the distance from the last station and locates his position on the sketch. He then carefully orients the board, and draws rays indicating the direction to all the important points to be located. During this process, and at the close of it, he should check the orientation of his board to make certain that it has not been disturbed. It is well, in fact, to check the orientation just before drawing any important line of direction.

Beginners have a tendency to attempt too many locations by intersection, with resulting waste of time and confusion of lines on the sketch. It is not necessary to draw rays to every visible object. The points selected should be first, of real assistance in the control and second, prominent points which can be readily identified from other stations.

Take advantage of every opportunity to check the orientation by sights on known points, the farther off the better.

If it be necessary to occupy some important point off the line of the main traverse, the sketcher runs a branch or secondary traverse out to the point, obtains there

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the data needed and then returns to his main route. The number of such secondary traverses should be no more than is absolutely necessary.

The sketcher should study his terrain as he proceeds, and especially at each halt. He should decide what locations he really needs, and then proceed systematically to make them, putting in the more important features first.

If the sketcher does not revisit his area for the purpose of sketching in the contours (having completed his framework), but completes his sketch by logical contouring, it will save him some time to put in the contour points between adjacent critical points having a uniform ground slope between them. If the slope between two points be convex or concave the contour points are adjusted accordingly.

Definite points should always be selected for important sights. Field glasses are very useful in picking out such points.

As the slope of streams is often very flat it is essential to note the direction in which a stream actually flows, especially if it is dry at the time. Otherwise the sketcher may later become confused, as a small error in some elevation might apparently reverse the direction of flow of a stream.

Progressive Instruction in Sketching.

We may now briefly review the items of practical instruction necessary to qualify the student as a competent sketcher. If he is able to make a good position sketch he will have no difficulty with outpost, place and route sketches, whose special features are discussed in a subsequent lesson.

Conventional signs. These are discussed in the course in Map Reading. The student should practice drawing these signs until he can make them neatly and legibly to the proper scale.

Master lines and critical points. As a preliminary to any work in the field the student should thoroughly understand the structure of the terrain, the laws controlling it, and the importance of the master lines and critical points. This will have been learned to some extent in the course in Map Reading, and the instruction should be continued by study of maps and actual ground forms, exercises on the sand table, and especially by logical contouring. Logical contouring should be continued throughout the course, during inclement weather when outdoor work is impossible.

Drawing the sketch. Before attempting an actual sketch the student should practice making up sketches of imaginary terrain, putting in conventional signs, and lettering for notes and title, until he can produce a sketch that is neat and legible. This instruction should also be continued as time is available, throughout the course. Students who are interested will practice out of hours, until they have acquired a satisfactory technique.

Control or framework. It is now necessary for the student to acquire a knowledge of what is meant by control, how it is established, and its importance.

All of the foregoing instruction may be conducted indoors. It having been satisfactorily completed, the foundation for successful sketching is laid, and the student may proceed to outdoor work.

Working scales. The first of the outdoor operations is to determine the sketcher's stride, to rate his horse (if mounted road sketching is to be undertaken), and to prepare the working scales for sketching.

Direction or orientation. The student should next practice the determination of direction by sun and pole star, and the orientation of the sketching board by compass, and by backsight.

Instruments and equipment. The next step is for the student to familiarize himself with the instruments and equipment used in sketching. This instruction may be had either in or outdoors.

Fundamental operations. The student next proceeds to perform each of the fundamental operations of sketching, in particular intersection, resection, traversing and the determination of elevations. These operations may be carried on both

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separately and, later, in combination. They should be continued until the student has acquired a reasonable facility in each.

Sketch with horizontal detail. A sketch of a small area (not over ½ sq. mile) should now be made, putting in horizontal detail only (no contours). Drainage lines should be included.

Estimating distances, slopes and elevations. From the beginning of outdoor work the student should take advantage of every opportunity for estimating distances, etc., and should in every case check the accuracy of his estimates until he is confident of his ability to make them within the permissible limit of error.

Sketch with critical points. As a preliminary to this the instructor should take his students for a "topographical walk" over an area which he has sketched, showing them all the operations actually performed. The students should then make a sketch of a small area, locate the critical points and complete by logical contouring. This exercise should be repeated on the same area, if practicable, until a good sketch is produced.

Complete position sketch. The student should now make a complete position sketch, putting in the contours in the field. A small area should first be sketched one or more times, and finally, if possible, an area of 1 sq. mile of average diversified terrain.

The foregoing constitutes a complete and thorough course in position sketching, conducted in a logical and progressive manner.

Outpost, place, route and panoramic sketching. These may be taken up in the order named, if practicable upon the completion of the preceding. It is useless, however, to give instruction in these forms of sketching to students who have not demonstrated their ability to make a satisfactory position sketch.

Other forms of area sketches, and route sketches, will present no special difficulties to those who have acquired reasonable facility in making a position sketch.

Outpost sketching. This is a form of area sketch, usually of terrain in front of an outpost line, in which the sketcher, while free to move along the front, is unable to actually enter the terrain to be sketched, due to its being occupied by the enemy or under his fire. Except for this limitation the sketch is executed by the methods heretofore described, and on the scale usual for area sketches, 6 inches = 1 mile.

If there be available maps or sketches of the terrain, to include the outpost line, the sketcher may utilize these as a control for the outpost sketch. If not, he will run a traverse along or close to the line of observation (parallel to the front), locating and plotting all points favorable for observation of the terrain to be sketched. From this traverse as a base, and by occupying the favorable points, the stream lines and critical points in front are located horizontally by intersection, or by compass sights and range finder or estimation of distance. Their elevations are determined by clinometer sights and estimation. The critical points being thus determined, the sketch is completed by logical contouring, aided by an actual view of at least part of the area.

There will, of course, be portions, often considerable portions of the terrain, on reverse slopes, and the lower portions of forward slopes, which cannot be seen by the sketcher. An experienced sketcher will often be able to "sense" with considerable accuracy the contour of the unseen ground. Thus for example, if the upper and lower portions of a stream can be seen, together with the crests on either side of the unseen portion, the sketcher cannot go far wrong in locating the entire stream. The stream and the crests on either side being located, he can sketch with considerable confidence the unseen slopes of the valley. Also, while a reverse slope directly opposite a certain point cannot be seen from that point, it will often be visible from some other point, especially a high salient in the line.

The contours of terrain which has not actually been seen should be drawn as broken lines to indicate that fact. A road which disappears over one crest, and reappears on the next forward slope may usually be assumed as continuous between its points of disappearance and reappearance, but should be indicated by a broken line, as there is always the chance of error in "sensing" unseen things.

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The sketcher should usually pass over the outpost line at least twice, first to locate the critical points and again to sketch in the ground forms.

If the elevation of the terrain is not known it may be assumed. The datum plane or zero elevation should be so taken that it is certain to be lower than any point in the terrain to be sketched, so that negative or minus elevations will not occur.

If because of exposure to hostile fire, a traverse cannot be run along the outpost line, it may be run at a safe distance in rear, and the favorable observation points in front located from this traverse. These observation points are later occupied by approaching them from the rear, and the sketch continued as heretofore described.

If airplane photographs of the unseen terrain be available, these will be of considerable assistance in completing the sketch. They afford no very positive direct evidence as to the contour of the ground, but they show the drainage lines, which will often enable the sketcher to complete his contouring, and they show also the roads, and isolated artificial features which otherwise could not possibly be discovered.

Field glasses, of course, are so useful as to be almost a necessity in outpost sketching. They enable the sketcher to discover critical points and features of the terrain which otherwise would escape his attention.

Place sketching. This is a very special case of area sketch, in which the sketcher is limited to a single point of observation. Like other area sketches a place sketch is usually made on a scale of 6 inches = 1 mile.

The important data to be obtained is the *distance* to critical points. There is of course no difficulty in determining their *direction,* nor their *elevation,* provided their distance is known. The sketcher should be equipped for this work, with a range-finder, a mil scale and field glasses. But it is possible, with patience and ingenuity, to determine the distances to a few important points, without the use of a range-finder, and without guessing at them.

If any object of known height or length, such as a man, a horse, a telegraph pole, or an ordinary house similar to other houses in the general locality, is visible, it is possible to determine its distance. The apparent height or length of the object is measured on the mil scale, or with the field glasses (which have a mil scale on the object lens). Suppose, for example, that a telegraph pole, known by comparison with other poles nearby to be 25 feet high, is found to subtend an angle of 5 mils. Then one mil at this distance will be 5.0 feet and the distance will be 1000 times this, or 5000 feet.

If a mil scale is not available it is very easily improvised by remembering that a mil is one thousandth of the range. Accordingly at a distance of 20 inches from the eye, 1 inch subtends an angle of $1000 \div 20 = 50$ mils. (Let the student prove this.)

In much of our western country the land is divided into squares 1 mile on a side, and these are subdivided into quarters. Roads, fences and hedges often lie along the sides of the squares, and where this is the case distances are easily determined.

The distances to a few important points having been determined with some accuracy, the remaining distances may be estimated, provided the sketcher is sufficiently skilled in estimating, and if he is not he cannot make a good place sketch. Thus if a certain house is found to be two miles distant, a skilful estimator can determine quite accurately whether some other house is $\frac{1}{2}$ or $\frac{2}{3}$ as far away. When a few critical points have been fixed the remaining ones fall into line quite rapidly, as in putting together a picture puzzle.

Points at the same elevation as the sketcher's eye are readily determined by zero sights with the clinometer. The elevations of critical points being fixed, other elevations are readily determined by estimation and interpolation.

The sketcher must not forget that as in all area sketching, the stream or drainage lines, ridges and hills, are the master lines and points of the terrain. He must patiently seek out the skeleton of his sketch, after which the ground forms are readily put in by logical contouring, aided by the field glasses. It is not points alone, but also lines which are of importance, as for example long tangents (straight lines) of roads or railroads. If the line of a road be determined by locating two points

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thereof, all houses, cross roads and other features along the road, are easily determined by single intersecting sights.

The remarks concerning unseen terrain and airplane photographs in the discussion of Outpost Sketching, apply with even greater force to Place Sketching.

Success in place sketching requires a sharp eye for the critical points of the terrain, and considerable skill in estimating heights and distances, as well as ingenuity in thinking out aids to such estimation.

If any choice of locality is allowed, the sketcher should select the highest available site to make his sketch. A place sketch cannot be executed from other than commanding ground. The higher the ground the greater the range of vision, the smaller the unseen areas, and the more complete and accurate the results. (Plate 40.)

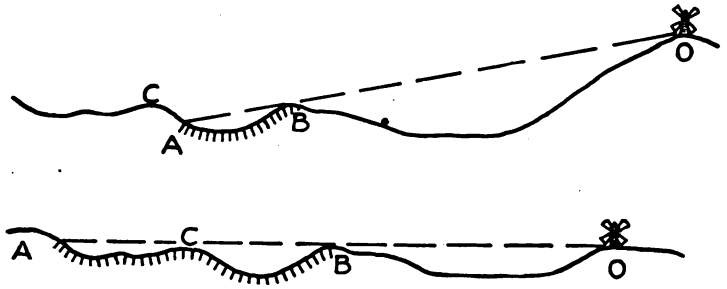

PLATE 40.—Advantage of High Point of Observation in Place Sketching.
NOTE.—In each case the invisible area is from *A* to *B*. From the lower point of observation this is half the terrain to be sketched, and the important ridge *C* would not be seen.

Notes.

See notes in preceding and in following lessons.

The outpost and place sketch are special forms of area sketching. While their application should be known to the students, practical instruction should not be attempted at the expense of position sketching which is more important. However, if suitable terrain is available, either at college or camp, the instructor may explain to the students, on the ground, the methods of making such sketches.

ELEVENTH LESSON.

Route Sketching.

Route sketching is of equal or almost equal importance to area sketching, and in very mobile operations will be more frequently required. The usual form of route sketch is the road sketch, to which the following remarks apply.

Road sketches are usually made on a scale of 3 inches = 1 mile, with a contour interval of 20 feet. They involve no principles nor methods not employed in area sketching, but are usually executed at greater speed and accordingly with a freer use of estimation of heights and distances. Therefore, in a progressive course of instruction area sketching should precede route sketching.

A road sketch covers a belt or ribbon of the terrain, including the road, and the country from 300 to 400 yards on each side. Isolated features of special importance and prominent landmarks outside of this strip, are usually included in the sketch. Their elevations, as well as horizontal locations, should be determined. In campaign it is executed in a single trip (one way only), and usually without leaving the road. For purposes of instruction the students, in making their early sketches, should pass twice over the route, putting in the control on the first trip, and filling in the topography on the second. They may also be permitted to leave the road occasionally to visit favorable points for observation, not too far away.

It is to be borne in mind that in a route sketch the most imporant item is *the route itself*. All necessary information concerning it should be conveyed by the

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sketch or notes thereon. In a road sketch for example, this would include: The nature and condition of the main route and its bridges, grades and alignment (bad turns), exposure to view or fire, branch roads, their nature and condition, and where they lead to, if this can be readily ascertained. The sketch will be of value if it shows nothing more than this, but to the extent that his skill and the time available allow, the sketcher should record all other important information which he gathers, such as: The topography adjacent to the road, water supply available, the buildings along the route with the names of their owners if readily ascertainable—especially large and important buildings, nature of the vegetation along the route, any good camp sites available, telegraph and telephone lines and where they lead to, etc.

Means of Transportation.

A road sketch may be executed by automobile, wagon, motor cycle, or horse, or on foot. These various means of transportation are given in the order of desirability. The horse or vehicle does not influence the method of making the sketch, and a sketch by automobile differs in no essential feature from one made on foot. The actual operations of sketching are all performed at a halt. The vehicle serves as a means of transportation, which saves the time and vital energy of the sketcher, and as a ready means of measuring distances (along the road only). It also, by its height above the ground, enables the sketcher to obtain a better view of the terrain than is possible when he is afoot. At a halt the floor or seat of a wagon or automobile (with the top down) affords a good rest for the sketching board, and a good view of the terrain. Important sights involving the use of the compass, should of course not be taken in or near an automobile, as the near presence of steel renders compass readings unreliable. When sketching in the machine orientation should be by backsight.

As to the horse, many sketchers prefer to travel afoot rather than be annoyed by the necessity of controlling the animal. As the time spent in moving along the road is usually less than that employed in sketching (at a halt), the saving in time by the use of a horse is less than might be supposed.

It is most desirable, in mounted sketching, that the sketcher be accompanied by an assistant also mounted, or at least an orderly. The assistant may perform any duties assigned him by the sketcher (for which he is competent), such as keeping a steady gait, and taking time between halts, carrying the sketching board, taking notes, calling the sketcher's attention to features of the terrain, ascertaining the names of owners of houses, or other information gained by question local residents, holding both horses during halts, etc.

The rating of horses for the measurement of distances in mounted sketching, and the use of odometers and speedometers have been heretofore discussed. Odometers and speedometers are not always reliable, and should be tested.

As speedometers are graduated in miles and tenths, working scales for use in automobile route sketching should be similarly graduated. The seasonal mileage reading should be noted at the beginning and end of the sketch, and at each halt. The trip mileage reading may be set back to zero for each course, but it is very important to beware of inaccuracies in small readings. In particular note the actual distance traveled at the time that the speedometer shows the first red figure, and whether it is always the same. If not it will be safer not to set the speedometer back to zero, but to use the cumulative or continuous reading only.

With these remarks concerning means of transportation the subject may be dismissed. The student's first road sketch should be made on foot, and his methods of procedure when provided with transportation will be the same.

Equipment for Road Sketch.

The instruments and equipment used in road sketching are the same as those employed in area sketching, and the fundamental operations are the same. For rapid work, elevations along the road are taken with an aneroid barometer. The

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elevations of points off the road are determined by clinometer readings and estimation. If an aneroid barometer is not used, elevations are carried forward during a road sketch by long sights with a carefully adjusted clinometer, preferably by zero readings, that is by determining points in advance (on or near the road) which are at the same height as the sketcher's eye.

A special form of sketching board known as the cavalry sketching case, has been devised for mounted road sketching. It is of smaller size than the regular sketching board, has a strap or band for attaching to the wrist, in lieu of a tripod, and certain special features such as paper rolls and ruler attached to the board. The cavalry sketching case is not regarded with favor by most sketchers, who prefer the standard board used in area sketching, and heretofore described.

In mounted sketching the tripod is sometimes dispensed with, as it is awkward to carry. Sketching is then done with the board held against the body, resting on a wall or other convenient place, or sitting down with the board held in the lap. For important sights requiring careful orientation the board is placed on the ground, the sketcher kneeling over it or lying prone. Most sketchers, however, prefer to use the tripod, even when mounted. The legs should be folded to a single length. When the board is set up the sketcher kneels or sits beside it. Important sights require a " set-up " and careful orientation. For less important sights, not essential to the control of the sketch, and for filling in detail, the board may be held against the body.

If mounted, the time between stations is taken with an ordinary watch, preferably attached to the wrist, or a stop watch. Upon arriving at a new station (where a halt is to be made) the time is at once read and recorded or plotted.

In passing from one station of the road traverse to another, the sketcher should ordinarily proceed continuously, not stopping to investigate everything he sees on the way. There will be no time for this in rapid road sketching. There must of course be exceptions to this rule. If necessary to stop on the way between two stations the sketcher records the number of paces up to the point, or stops his watch. On resuming travel he takes up the count of paces, or starts his watch, at the point where he left off, so that the record will be continuous from one station to the next.

As he passes along the route the sketcher carefully observes the terrain on either hand and makes mental note on a written record in some form, of the important features, which he sketches in at the next halt. The distance between halts should not be very great, especially for an unskilled sketcher. From 250 to 300 yards is ordinarily enough, unless the sketcher be skilled or the terrain " easy."

Record Pad for Mounted Sketching.

As an aid to memory in recording important data gathered between stations, in mounted sketching the pad shown in Plate 41 was devised. This pad may be purchased from the Book Dept. at Fort Leavenworth, it measures about 3 x 9 inches. The heavy horizontal lines represent minutes of travel, the light lines quarter minutes. The spaces between vertical lines represent 100 yards, the unit of distance for estimation. A stop watch may be attached at the top of the board. The central column represents the road on which the sketcher is traveling. As important features are passed they are placed on the pad in their proper positions relative to the road, utilizing the time scale along the road, judging directions, and estimating distances to the right and left. These notes are made mounted, and without checking the horse, in order that the time records between stations may be continuous. As little time as possible should be spent in making the notes, as the sketcher must utilize all possible time for studying the terrain as he moves along. With a little practice the notes may be made even at a trot, by rising in the stirrups and pressing the elbows against the body. As both hands will be required, the reins must be dropped on the horse's neck while making notes. It will be well to put a knot in the reins, which will fall just in front of the pommel and make it easy to recover them.

In sketching on foot, details between stations are recorded directly on the sketch, instead of using the record pad.

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Procedure in Road Sketching.

The operations in a road sketch consist of an accurate traverse along the road, the location of important points on either side by intersection, or offset and estimation, and the filling in of topography *as the sketch proceeds,* by the same methods as in area sketching. The traverse is executed exactly as heretofore described for area sketching. The sketcher must be able to estimate distances up to 400 yards with a considerable degree of accuracy.

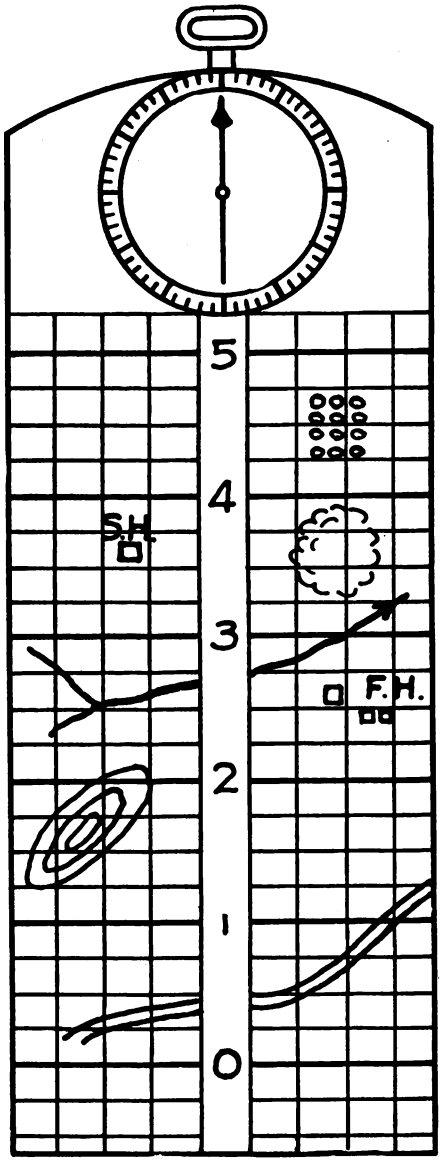

PLATE 41.—Record Pad for Mounted Sketching.

The sketcher has noted in order a road crossing the main route, a knoll to the left, a farm house and outbuildings to the right, a stream with one tributary, a small wood on the right, a school house on the left and an orchard on the right.

The drainage lines, hills and ridges, are the critical features of the terrain, as in all topographical sketching. If the sketcher makes an accurate traverse and locates the drainage net, he will have little difficulty in filling in the topography from his general knowledge of the laws governing ground forms.

In campaign the sketcher will seldom leave the road, and will usually have no opportunity to pass over it a second time. Accordingly all work must be completed as he goes. This will require frequent estimation of heights and distances. Commanding points not too far off the line of the road, may be occupied when necessary. Stations on the road, at which halts are to be made, should be on high ground affording a good view in all directions, whenever possible. This will make it unnecessary to leave the road.

Ground forms (contours) are of relatively less importance in road sketching than in area sketching. It *is* important that the user of the sketch should be able to follow the road indicated, and recognize the principal localities on or near it. If there be not time to put in all the contours certain features of the terrain may be indicated by their characteristic form lines, or contours without reference numbers. For example, if there be an important ridge a mile or so to one side, it may be indicated by giving the positions and heights of the ends of the ridge and then indicating a ridge by form lines, without detailing the exact contour of the slopes, which will usually not be required.

As distances and slopes are measured along the road it is a common mistake of beginners to draw their contours perpendicular to the road, as if it ran at right angles to all ridge and valley lines. Such a sketch is manifestly worse than useless so far as any information concerning the topography is concerned. It should be remembered that the road itself has no influence upon and no relation to the configuration of the terrain. The latter was there first, and the road was built later, and did not in the least alter the adjacent terrain.

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In road sketching it is not essential that the edge of the sheet be a north and south line. If the general direction of the road to be sketched is known, it is well to assume the starting point and direction in such a manner as to include as much as possible of the road within the limits of the sheet. If the road runs off the paper, draw a line square across, and begin again to the left or right (Plate 42). The orientation of the new portion may be changed if found advisable. The sketch is later matched by cutting the sheets along the lines drawn across them, and fitting the sections of the road together in their proper positions, making certain that the meridians of all sections are parallel each to each.

Hints for Road Sketching.

The following hints and precautions will be of assistance in road sketching.

Do not attempt to traverse out or read slopes along every short section of road, setting up the board at every minor change of direction. Take long sights, at least

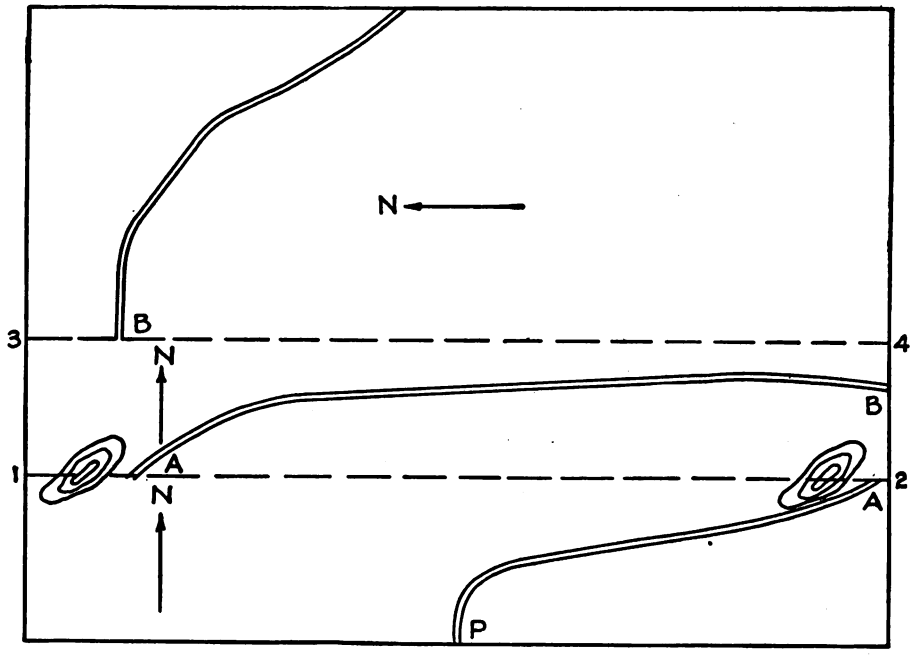

PLATE 42.—Joining Sections of a Road Sketch.

The sketcher not knowing the general direction of his road, starts at the middle of the lower edge of the sheet *P*. When the road runs off the map at *A*, he transfers the point *A* to the left without changing his meridian. The road again runs off the map at *B*, which is transferred to the left, and the orientation of the board is changed. The three sections are fitted together, first cutting the sheet along the lines 1-2, 3-4. The meridians must be parallel to each other.

250 yards, and as much more as possible, disregarding minor changes of direction which may be put in by estimation. In like manner carry forward the general elevation by long clinometer sights, preferably zero sights (to points at the same elevation as the sketcher's eye), as these are independent of the distance. If either traverse or level be carried forward by a succession of short sights, cumulative errors are almost certain to result. The elevations of intermediate points may be determined by estimation, by *comparative* readings of the aneroid barometer, or by independent clinometer readings. Time may be saved by setting up at alternate stations of the traverse, where it has been necessary to take short sights.

At each station set up and orient the board, and perform first all work for which careful orientation is necessary (*i. e.*, forward reading to next station, direction

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lines to all important localities). Thereafter the orientation of the board is of less importance, and details may be sketched in with the board approximately oriented and held against the body or on the lap.

Take the elevations of all important points located by intersection, and indicate the general nature of topography more than 400 yards from the road (but which is of military importance) by form lines.

Details near at hand along the road are generally located by the method of offset and estimation of distance and elevation.

Gather all possible information concerning drainage lines which cross or run near the road, even if it be necessary to halt between stations to do so.

Halts should be made at localities favorable for observing the terrain. Ordinarily the sketcher will remain on the road, but specially favorable observation points close to the road may be occupied when necessary.

Note and plot all roads and railroads which cross the route of the sketch and indicate where they lead to (in both directions).

Give the names of local residents along the route and local names of all important landmarks. Record by note any information of military importance obtained from local inhabitants or other source.

The remarks concerning unseen areas under Outpost Sketching apply to Road Sketching. Unless the sketcher is reasonably sure of the contour of unseen terrain, it should be omitted. It is better to allow the user of the map to judge for himself than to tell him something that is not true.

Above all do not waste time over minute details.

Combined Sketching.

Combined sketching is the operation of mapping an area of several square miles, or a road net, by the simultaneous work of several sketchers.

The operations of the individual sketchers are as heretofore described; the problem is rather one of organization and co-ordination.

Combined Road Sketch.

The following organization and procedure for a combined road sketch has been found to give good results.

The party consists of a director, a principal sketcher and a number of assistant sketchers, for each main route leading to the front.

Each director is equipped with an aneroid barometer, all of which are set to the same reading on starting the sketch. The director of each party rides the main route in advance of his assistants. At each road junction he posts a card with an arrow indicating the route of the principal sketcher, the serial number of the branch route, and the elevation of the junction point.

The principal sketcher sketches the main route, and the assistant sketchers take the branch roads in succession.

Each assistant sketcher before starting on his route, places his initials on the card at the junction. He marks his sketch with the serial number of his route. He then sketches his route as far as the next main route, and initials the card at the junction point. If he meets a sketcher from another party, they compare sketches, and mark on each the point of meeting. The assistant sketcher then returns to his own main route, and sketches the next branch route which he finds not initialed by another sketcher.

A rendezous is indicated at which all sketches are turned in. They are then fitted together to form the combined map.

A sketch of a road net is readily converted into an area sketch by filling in the intervening spaces between roads.

Combined Area Sketch.

If any map of the area is available, it is divided into a number of tasks, one of which is assigned to each sketcher. If the map is a good one it may be enlarged

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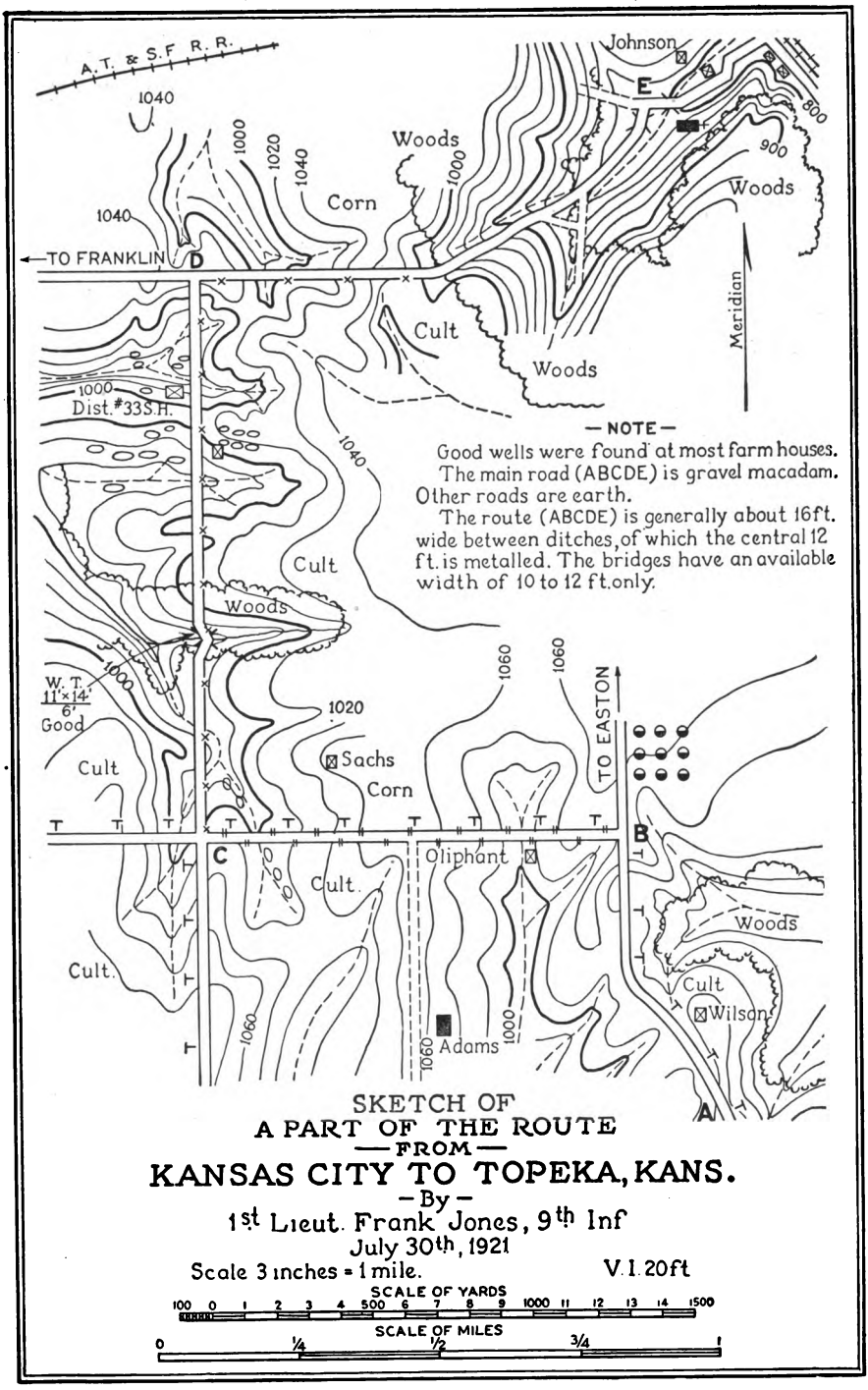

PLATE 43.—Road Sketch.

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to the scale of the sketch, and a section given to each sketcher, for his guidance and control.

If no map is available the front is divided into sections equal to the width of two tasks. The directors then ride to the front along the lines of divison (whch are preferably roads), assigning their assistants at proper distances, to sketch the areas to the right and left of the axis, the procedure being similar to that of a combined road sketch. Better results are obtained if the main route is sketched and then cut along the line of the route, the sections being handed in order to the assistant sketchers for completion. Whenever possible the boundaries between tasks or areas should be well defined lines of the terrain, such as roads or streams, and should be shown on both adjacent sketches. It is well for two men sketching adjacent areas to proceed together along the common boundary which insures the two sketches fitting together.

Proper identification marks are placed on each sketch, all sketches are then fitted together, and the whole retraced.

Airplane Photographs.

Airplane photography is a most valuable means for the rapid mapping of areas, especially within the enemy's lines. It has the great deficiency of not giving definite information as to ground forms, and accordingly is far from being a complete substitute for a contoured map or sketch.

Reconnaissance.

A military reconnaissance is an examination of a route or area for the purpose of obtaining information for military use.

A reconnaissance should have a well-defined purpose. The specific information desired should be plainly indicated to the officer making the reconnaissance, in order that his time may not be wasted on matters of no immediate importance. Nevertheless all officers should cultivate the *habit of observation* until it becomes second nature. In making a reconnaissance for any purpose, or a sketch, an officer should observe everything in sight, and make note of anything which he thinks may be of use to his superiors. In other words officers should keep their eyes open and their wits alive at all times, and should cultivate their faculties of observation and interpretaton, and their memories.

Sketches with reconnaissance reports. A reconnaissance report is usually more valuable if accompanied by one or more sketches. If an officer has been directed to reconnoiter a route he should make at least a rough sketch of the route. A reconnaissance report of a hostile position will be much more valuable if it includes a few landscape sketches indicating the nature of the terrain occupied by the enemy, etc.

A reconnaissance for any specific purpose should, when possible, be performed by an officer specially selected for his knowledge and skill. For example a bridge reconnaissance is best made by an engineer officer having expert knowledge of bridges. However the engineer officer is not always available, and infantry officers may be required to report upon any matter of military importance. This is merely one phase of the general truth that in war time there is nothing that an infantry officer may not be called upon to do.

A number of government manuals give in detail the information to be sought in reconnaissance for various purposes, and how it is obtained. An officer detailed for reconnaissance should familiarize himself with his subject and lay a program of procedure. He should provide himself with a map of the locality to be visited, as well as a guide and interpreter (if necessary).

The following are a few of the subjects of military reconnaissance, with the salient points to be noted in each case. They are given as examples only.

Information Sought in Reconnaissance.

Bridges. Span. Width of roadway. Height above water. Nature of foundations and type of superstructure. Grade of approaches. Probable safe loads. Con-

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dition of all parts of structure. Repairs needed. Material required and locally available.

Fords. Width. Depth. Nature of bottom. Swiftness of current. Nature and grade of approaches. Access to roads on either bank. Cover and defensive facilities available. Work required to make practicable.

Towns. Population. Number and type of buildings. Billeting capacity—men and animals. Large buildings available. Railroads and telegraph lines, including depots, sidings, loading facilites. Roads. Principal industries. Stocks of food, lumber and other materials on hand. Water supply. Defensive features.

Railroads. Name. Termini. Single or double track. Nature of road bed. Gauge. Weight of rail. Important bridges, tunnels, cuts and embankments. Grades and curves. Stations, sidings, loading platforms. Water tanks. Repair shops and roundhouses. Turntables. Rolling stock available.

Roads. Width. Nature and condition of surface. Drainage. Grades, including length of important grades. Bridges, cuts and embankments. Can infantry march in fields alongside? Branch roads—where to? Exposure to enemy fire or view. Defiles.

Water supply. Streams, lakes, springs, wells and town water systems; location and probable capacity. Potability of water.

Camp sites. Area available. Shelter from wind, view and fire. Trees. Water, fodder and fuel. Nature of soil and drainage. Access to roads and railroads. Has site been previously occupied? Where would the outpost be placed?

Information concerning the enemy. This is always a matter of the greatest importance. Any material evidence of the enemy's recent presence should be carefully noted, and the local inhabitants should be questioned concerning him. The number of the enemy seen, the arm of the service and if possible the actual organization to which they belonged, whence they came, how long they stayed and whither they departed, what they did and what information they sought; are all of special interest. Information obtained from inhabitants, even friendly inhabitants, should be taken for what it is worth and not accepted as truth unless corroborated.

Notes.

Outpost, place, road and combined sketches, while of importance, should not be undertaken until the students have acquired a reasonable proficiency in position sketching. At the average institution there will be little enough opportunity to accomplish the latter in the time available. In such a case practical instruction in the sketching described in this lesson will form no part of the course. A few of the students, of exceptional aptitude, who have demonstrated their ability to make a position sketch, may be given practical instruction in road sketching, on foot or by automobile. It is a waste of time as well as a discouragement for a student who has not mastered the fundamentals, to attempt a road sketch.

While practical instruction in these subjects will not always be given, it is desirable that the students should have a general knowledge of the nature of outpost and road sketches, and the methods of procedure in each. It is, therefore, recommended that this lesson be included in the course of theoretical instruction if possible.

Reconnaissance is so important a duty that a little practical instruction in the subject is most desirable, sufficient, at least, to give the students a conception of what reconnaissance means and how it is conducted. If transportation can be secured, and time is available, the instructor may take his students for a ride over a few miles of road and through one or two small towns. A military situation should be assumed, as for example that a small force including such and such troops and with such and such equipment, is to pass over the route, stopping one or two days in one of the towns. Certain information concerning the enemy should be assumed. As the trip proceeds the instructor calls the attention of the students to various details of military importance, such as: The main route, bridges and defiles, branch routes, railroads, the town, its billeting capacity and camp sites near at hand, where foot troops, artillery and trains would be camped, where the outpost would be

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located, water supply, food stuffs in the town, rail and telegraph connections, etc. The students should be required to take notes of what they see, and on their return to write a report of the reconnaissance, indicating also what sketches they would, in an actual case, submit with their reports.

TWELFTH LESSON.

LANDSCAPE (PANORAMIC) SKETCHING.

Usefulness of Landscape Sketches.

A landscape sketch, in perspective, serves many useful purposes in military operations, and it is desirable that every officer be able to make a simple sketch of this nature.

For the designation of artillery targets such sketches are indispensable, and are made at every artillery observation station. They are also very useful to the infantry as a means by which new troops entering the front lines in an unknown sector can promptly identify the important features of the terrain and dispositions of the enemy in their front. Reports on reconnaissances of hostile positions are much more intelligible and useful if illustrated by landscape sketches.

Small marginal perspectives on a road or area sketch are of great assistance in identifying important localities, such as road junctions. They should be carefully referenced by a mark on the map indicating the point of view and the direction in which sketcher was looking.

A collection of panoramic sketches should if possible, be accompanied by an index map, showing by reference numbers the exact point at which each sketch was made. The direction in which the sketcher was looking is indicated on the sketch itself. A properly equipped observing station should include both topographical maps and panoramic sketches of the terrain under observation. Each of these conveys information not given by the other. The map shows the actual location (distance) of all points. The panoramic sketch shows the important localities as they appear to an observer, and enables them to be readily identified. (Plate 49.)

Landscape sketches have an advantage over topographical sketches and maps, in that no training in map reading is required to interpret them. They are more useful than photographs in that all details not of military importance (which merely obscure the important items) may be omitted. Important features, even though too distant to show at all in a photograph, may be emphasized so that they will not be overlooked.

Sketching in perspective is instinctively shunned by the average officer or man. Actually it requires no more, if as much, training and skill as topographical sketching. A knowledge of the principles of perspective and a little aptitude for sketching are undoubtedly an aid. But the necessary knowledge of perspective is soon acquired by practice, and the whole operation may be performed in an entirely mechanical manner, artistic skill being unnecessary. To many, panoramic sketching is easier than topographical sketching. The average man therefore need have little fear of not being able to acquire satisfactory proficiency in landscape sketching, if he makes an honest effort to do so.

Landscape sketching is an excellent method of cultivating the habit of observation so essential to military men. It educates the eye in the interpretation of ground forms and the estimation of heights and distances. The constant study of the landscape develops a faculty for unconsciously noting the form, color and location of objects, which are mechanically impressed on the memory, even though the mind be occupied with other thoughts.

Simple Rules of Perspective.

A knowledge of the mathematics of perspective is not essential to the landscape sketcher. But a few simple rules of perspective will enable the sketcher to fill in details more rapidly and accurately, and portray relative distances correctly. The more important of these rules are as follows:

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a. All lines which are vertical will appear so in perspective, for example: Trees, telegraph poles, edges of buildings.

b. All straight lines will appear as straight lines in perspective.

c. The size of objects in perspective is inversely as their distance from the eye. That is if there are two objects of the same size, one 200 yards and the other 400 yards from the sketcher, the former will appear twice as large as the latter. This rule will be of assistance in estimating distance.

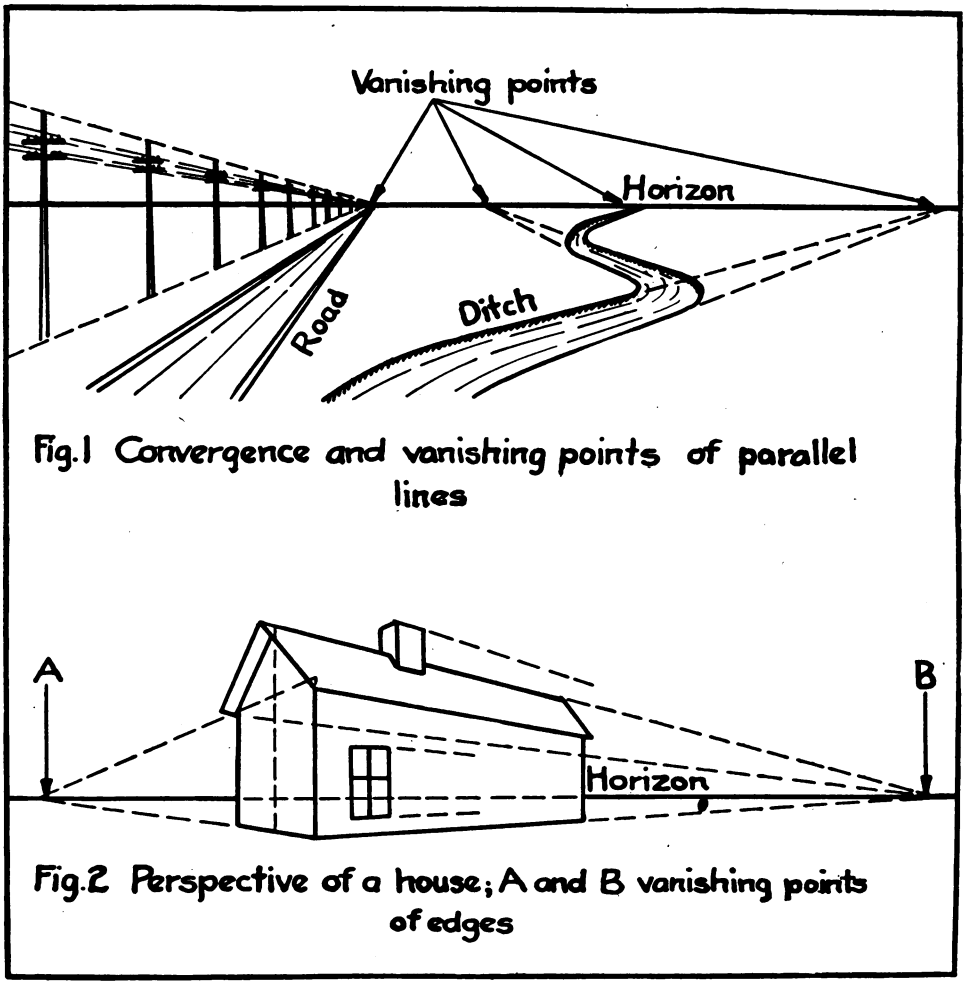

PLATE 44.—Simple Rules of Perspective.

d. Two lines which are parallel (whether or not they are *straight*) appear in perspective to *converge* or come closer together as they recede into the distance. If the distance be great enough the lines eventually appear to meet at a point, which is called their vanishing point, the farthest point at which they are visible. If the lines slope *upward* they vanish *above* the horizon (level of the sketcher's eye), if *downward,* below the horizon. If level they vanish *on* the horizon. The vanishing point of lines is usually readily recognized.

This rule is of the greatest assistance in portraying such common features of the landscape as roads, railroads, lines of telegraph poles, rows of trees, fences, etc., whose proper portrayal gives a pleasing and realistic effect.

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The parallel edges of buildings never appear to meet, because of their limited length. But they would meet if extended, and a building will present a much more natural appearance if its parallel edges are made to converge noticeably, instead of being drawn parallel to each other. It is not necessary that this be done with mathematical accuracy. The convergence should be *noticeable* without being *exaggerated.* Of three equal vertical edges of a building which are visible, the one nearest the sketcher will be noticeably longer than the others. The ridge line of the roof will always appear to slope downwards unless its two ends are equally distant from the sketcher.

In drawing two lines known to be parallel, but which do not appear so, or do not continue to a meeting point, imagine them prolonged and fix the approximate position of their vanishing or meeting point. Then cause the prolongations of both lines to pass through this point.

e. It is never possible to see more than two sides of a rectangular building (or any similar object) from any point.

The application of these simple rules will be evident from an examination of Plate 44.

Simplicity in Execution.

Artistic effect is not sought in military panoramic sketching. All details not of military importance are entirely omitted, and others are indicated in outline only. The utmost simplicity should characterize the sketch. The smaller the number of lines the more easily it is deciphered. In particular large, unimportant details in the foreground (which would be very prominent in a photograph), should be suppressed. There should be no unnecessary shading. In general tree masses only are shaded. Very steep cliffs or embankments and cultivated land in the foreground may be lightly shaded if necessary to make them clear. (Plate 47.)

The beginner will be confused by the mass of detail which confronts him. He must learn to show outlines only. Accuracy in the detail of such features as houses is of no importance, provided the objects are sufficiently clear to be identified.

The effect of distance will at first be difficult to secure. It is given by the comparative size and clearness of objects near and far. The sketcher should carefully note the effect of distance on the apparent size and distinctness of objects. Features in the distance are portrayed by fine strokes with a relatively hard pencil, and the weight of lines increases towards the foreground, where a soft pencil and heavy lines are used. It will be of advantage to the beginner to use several weights of pencils (two or three), for example: Nos. 3 and 2, or 3H, H and HB, or 4H, 3H and H, etc., for distance, mid-distance and foreground, respectively.

No conventional signs (except as below) are used in landscape sketching, but objects are drawn in outline as they appear. Troops, intrenched positions, artillery and machine guns are indicated as in Plate 47.

The landscape is drawn *as it appears,* all objects being shown in outline only, and of their proper apparent size according to their distance. Features of special military importance are indicated by vertical arrows pointing down from the sky (see Plate 47), and their distances (range) and deflection from the reference point of the sketch are given for the benefit of the user. Ranges are determined by range finder or by estimation, deflections are measured in mils by the mil scale, by graduations on the object lens of a field glass, by aid of vertical guide lines on the sheet, by finger or pencil held a certain distance in front of the eye, etc. Thus at a distance of 20 inches from the eye 1 inch subtends an angle of 50 mils. The distance from the eye to the mil scale or drawing pad is fixed by means of a string of proper length attached to the scale at one end and having at the other a knot which is held in the teeth.

No special equipment is absolutely necessary for landscape sketching. A skilful sketcher requires only a pencil and a sheet of paper. For the average man certain mechanical aids, as heretofore noted, are helpful.

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Reference Point and Meridian.

Every panoramic sketch must have a reference point from which deflections are measured, and a magnetic meridian by means of which the magnetic bearing of the line from the sketcher's position to the reference point is indicated for the benefit of the user. (Plate 48.) The reference point is some prominent feature of the terrain, preferably near the middle of the picture, such as a church spire, a gap in a ridge, etc. It is not necessary that it be in the enemy's lines. A prominent peak, several miles distant is a satisfactory reference point. Deflections to other points are measured to right and left. A panoramic sketch does not give distances or ranges except to certain important points, which are noted in the upper margin of the sketch, on the line provided. Such notes should always indicate whether the distances have been determined by range finder or estimated.

The magnetic meridian is placed in one of the margins of the sketch, usually at the bottom (Plate 48) as follows: Having completed the sketch, lay the pad or board in a horizontal position with its upper edge away from the observer. Lay the alidade along the right or left boundary of the sketch, or parallel to any vertical line thereof, and sight along its edge on the reference point of the sketch, exactly as in orienting by backsight in topographic sketching. The board being oriented, place the compass upon it and draw a line parallel to the needle, marking its north end with a half arrow-head. This will be the magnetic meridian of the sketch. The angle between this meridian and any vertical line of the picture will be the same as the angle between the meridian (on the ground) and the line of sight from the sketcher's position to the reference point.

Point of View.

In making his sketch the sketcher first selects some prominent and easily identified point affording a good view of the landscape to be sketched. This point should be carefully described on the sketch itself, and also located on the index map, if there be one. If there be no index map a small plan showing the exact location of the point of view with reference to buildings, cross roads, in the vicinity, etc., may be drawn on the margin of the sketch. It is of great importance that the user of the sketch should place himself exactly at the locality from which the sketch was made. The features appearing on the sketch will be in their correct relative positions only for an observer so located. This is one disadvantage of a landscape sketch as compared to a map.

Executing the Sketch.

Before starting his work the sketcher will do well to carefully examine the terrain, using his field glasses, if he has such, and noting the important features. The skyline is then drawn, after which the sketcher works toward the foreground, gradually increasing the weight of his lines. All crest lines, as well as the skyline, are shown (Plate 46). To put in tree masses (woods) sketch the outline of the tree tops with a succession of short curves, draw a broken line to indicate the near edge of the woods, and fill the intervening space by diagonal shading. This is the only shading ordinarily required on the sketch (light and shade on hillsides are *not* indicated) and the tree masses are accordingly the most conspicuous feature of the sketch. The outlines of the tree masses conform to the topography, indicating the depressions and undulations of the terrain. Roads are indicated by two unbroken lines which gradually converge and may unite as the road recedes into the distance. All other features are shown in outline only. Unimportant details in the foreground should be omitted.

An expert sketcher, having some artistic talent, may produce a more pleasing sketch, showing more shading and detail other than indicated above. The average sketcher should attempt nothing of the kind, bearing in mind that the utmost simplicity should characterize his sketch, and that military usefulness and not artistic or pleasing appearance, is the end sought.

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For purposes of training the same landscape should be sketched several times, until satisfactory results are obtained.

Scale and Visual Angle.

While landscape sketches may be made to any size or scale, it is desirable that sketches for military purposes be of small and standardized size, generally a single sheet should not exceed 6 x 9 inches (to edge of sheet), and the sketch should cover a visual angle of about 30°. If an extended panoramic is required it is made by joining several sketches. (Plate 48.)

Methods of Landscape Sketching.

There are several different methods of making landscape sketches, and each sketcher will develop habits of his own. Any method is satisfactory that gives the desired results. Those described in the following pages have been developed by the U. S. Army and have been thoroughly tested in practice.

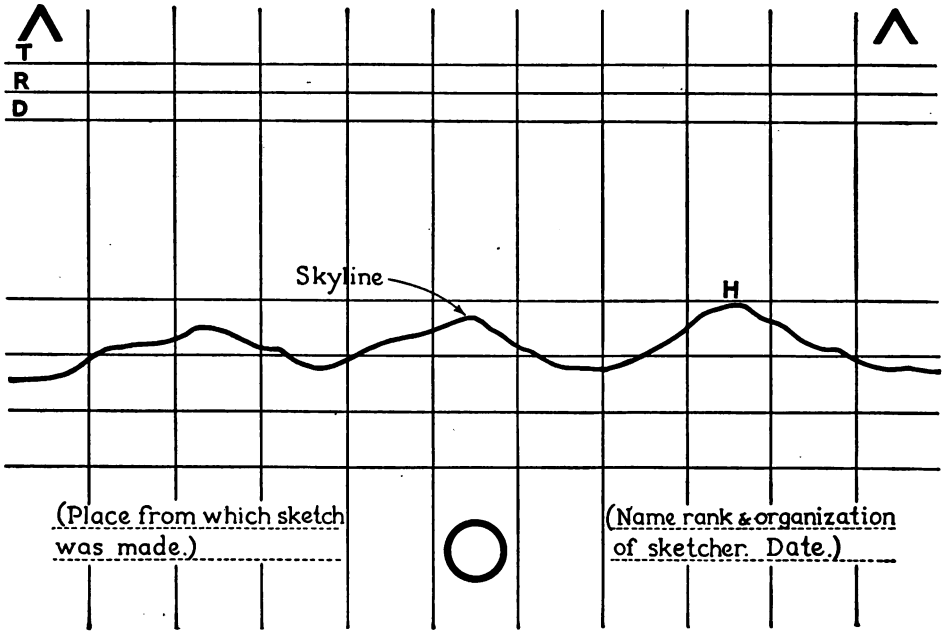

PLATE 45.—Standard Sheet for Landscape Sketching.

Sketching pads. The sketches are made on a pad of specially ruled paper (Plate 45). The sheets are 8½ x 5½ inches. The guide lines are in light blue. The interval between the vertical lines subtends an angle of 50 mils when the pad is held 15 inches from the eye, which is done by means of a cord through an eyelet in the backing of the pad, and a knot on the cord, held in the teeth. The horizontal guide lines at the bottom of the sheet (4 in number) inclose a strip 1½ inches wide, marking the limits of the sketch.

At the top of the sheet are two heavy orientation marks, and three horizontal lines marked *T, R* and *D,* for recording the name of the target, its range and deflection. At the bottom of the sheet are spaces for description of the place where the sketch was made, the hour and date at which made, and the name, rank and organization of the sketcher. There is also a circle containing the serial number of the sketch, and the magnetic meridian.

Making the sketch. Face the sector to be sketched, with the cord held in the teeth. Raise the pad until the landscape appears just over the upper edge, close one

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eye and move the pad laterally until the desired sector is included between the orientation marks on the pad. If it be desired to cover a wide sector the pad may be held closer to the eye than 15 inches, in which case the interval between the vertical guide lines will be more than 50 mils. It is better to use the standard distance (15 inches) and make as many sketches as necessary to cover the desired sector. For military purposes standardization in landscape sketches is desirable, as it is in most other things. Sketches will be more readily interpreted and more useful if the same interval on the sketch represents always the same visual angle.

The features of the landscape are now seen over the top of the pad, in their proper relative positions. Select a prominent point (preferably distant) as a reference. It is well to have this point fall exactly on one of the vertical guide lines, even if it be necessary to move the pad laterally a short distance, as it will then be much easier to read the deflection of other features.

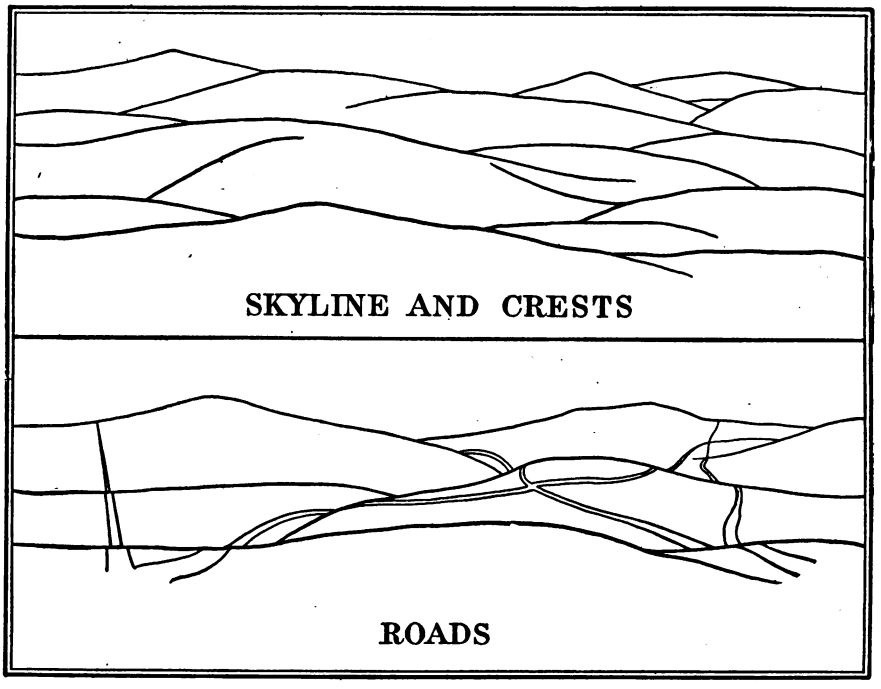

PLATE 46.

The pad being oriented as above, place marks on the upper edge of the sheet opposite the critical points (changes of direction) of the skyline, and then by the aid of the vertical and horizontal guide lines transfer these points to their proper horizontal and vertical positions on the sketch, placing the highest point of the skyline on the upper horizontal line (*H*, Plate 45), thus fixing the highest point of the sketch. Now connect the points thus determined by a light line. This will be the profile of the visible horizon. Other crest lines, important points, targets, etc., are transferred to the sketch in like manner (Plate 47). When a few of the important features have been sketched in, the practical sketcher will be able to place the remaining features by judgment, without re-orienting his board.

The immediate foreground is indicated by a very heavy line above the circle. This may be made by using the side of the pencil point. (Plate 47.)

By this method the lateral portions of the sketch will be fairly accurate. The vertical should be slightly exaggerated. No effort need be made to effect this, since most sketchers will do so unconsciously.

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Relative vertical proportions may be determined with accuracy by moving the pad laterally until the highest point on the horizon is just visible past the right edge. Hold the uppermost horizontal blue line on this highest feature and mark with a pencil the points where lower features appear along the edge of the paper. Transfer these elevations to their proper places in the sketch. (Plate 47.) The positions of the fences, roads, woods, buildings, and other features of possible military value must be included. Features of the foreground are omitted unless of military importance.

Identification marks and notes. The reference point of the sketch is identified by a vertical arrow, drawn from the top of the sheet and stopping just above the point. (Plate 47.) Preferably this arrow should coincide with one of the vertical guide lines. It is marked with a large zero, indicating the origin from which deflections are measured both ways.

Other important points may be indicated in a similar manner, by means of arrows. (Plate 47.)

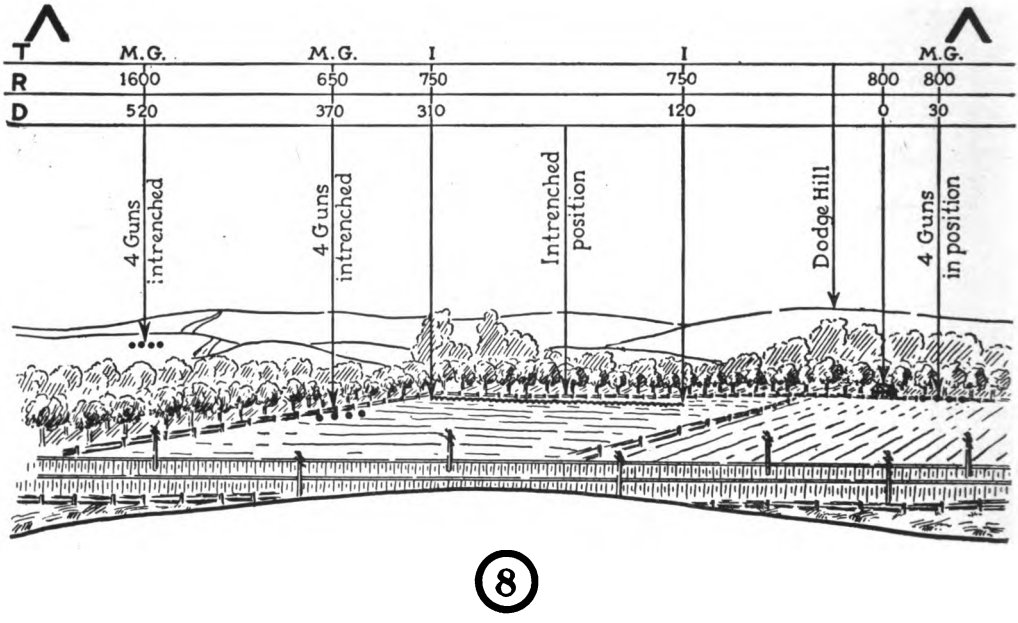

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PLATE 47.—Completed Landscape Sketch.

On the line marked *T* at the top of the sketch, is entered a description of the reference point, and of other important features.

Conventional names or numbers may be used for localities whose actual names are unknown.

Intrenched positions, and artillery or machine guns in position, are shown by simple symbols. (Plate 47.) An intrenched position of some length may be indicated by a vertical arrow at each end.

The ranges (as measured or estimated) and the deflections of important points, are entered on the proper lines at the top of the sheet. The deflection in mils from the reference point is determined either by use of the vertical lines on the pad or by means of a mil scale, and entered on the *D* line across the perpendicular indicating the target or object.

This deflection should never be in error more than 10 mils. Place a reference point on each sketch. Do not carry the deflection across several joined sketches. The sketch containing the first reference point may be lost, and thus make the others valueless. Each sketch must be complete in itself.

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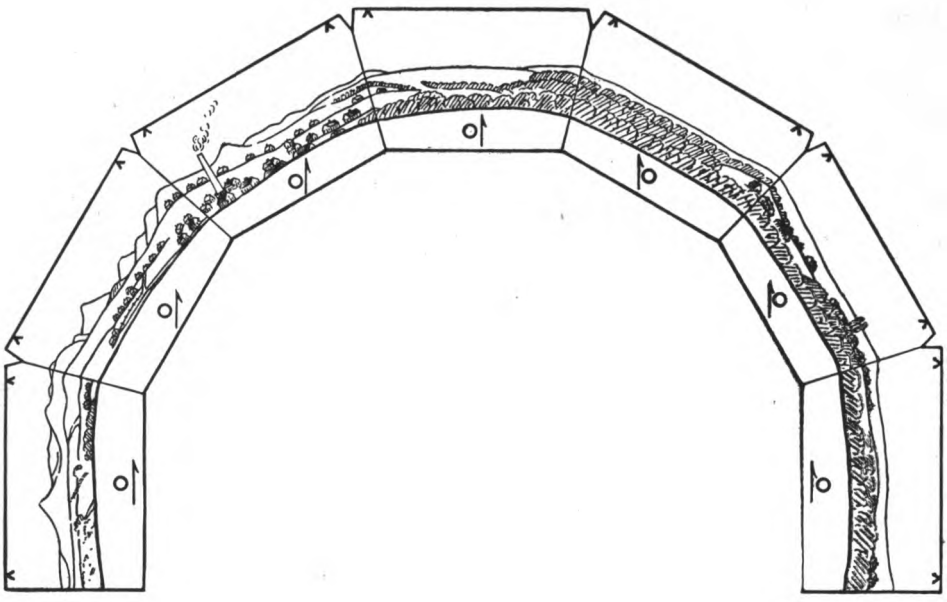
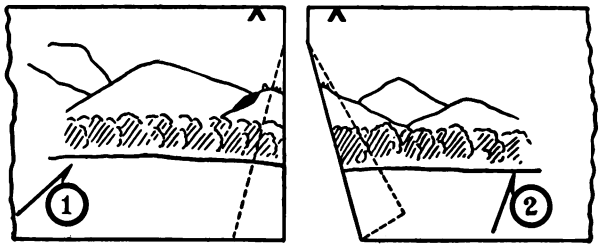
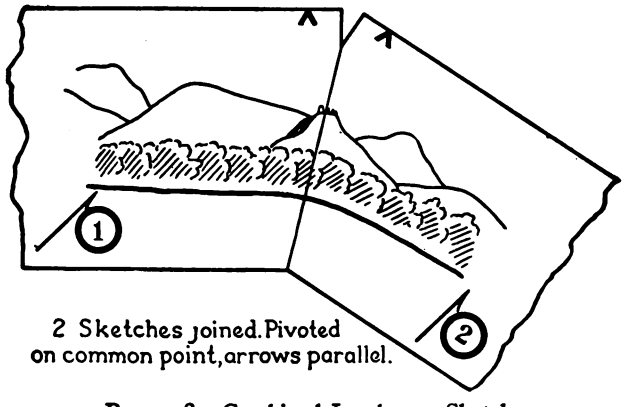




Corner of sketch on right folded through center of reservoir hill preparatory to placing over sketch on left.



2 Sketches joined. Pivoted on common point, arrows parallel.

PLATE 48.—Combined Landscape Sketches.

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The location of the sketcher is described by using the name of the ridge, knoll, etc., or by giving the direction and distance from a known point, as—

"Evans Knob," or

"Ridge 400 yards west of Apache Gate."

This data is entered in the lower left-hand corner of the sketch and may be amplified by a small plan of the locality.

The sketches are numbered serially within the circle at the bottom of the pad. The location and direction illustrated on a route sketch are identified by the corresponding number in a circle, with an arrow indicating the magnetic meridian.

The time, date, signature, rank and organization of the sketcher, entered in the lower right-hand corner, complete the sketch.

Joining Sketches.

For an extended panorama several sketches are made on the same scale and pieced together on the chords of a circle. (Plate 48.)

When sketches are to be joined they must overlap, the same features appearing on the right of one sketch and the left of the next.

The procedure is as follows: Make a complete sketch as far as the right edge of the paper. The next sketch to the left will commence with the left orientation mark over some feature shown on the right of the preceding sketch, this feature appearing on both sketches. This process is continued until the required sector of the terrain is covered.

A series of seven sketches may be made, for example, from one position, giving a panorama of about 180°. If this panorama extends from the east through the north to the west, the arrow on the first sketch indicating the magnetic bearing will lie parallel to the bottom of the paper pointing to the observer's left, the arrow on the fourth sketch (looking north) will lie at right angles to the lower edge of the paper, pointing toward the top, and the arrow of the last sketch (looking west) will lie parallel to the lower edge of the paper, pointing to the observer's right. The arrows of the second and third sketches will occupy intermediate positions with reference to the lower edge of the paper between those of the first and fourth sketches, and the arrows of the fifth and sixth sketches intermediate positions between the fourth and seventh. (Plate 48.)

In assembling to form a panorama the sketches are placed in order on a flat surface with all the arrows parallel. In the above example, a panorama extending through 180°, the sketches form a semicircle.

In joining two adjacent sketches, the corner of the right sketch (for example), is folded under in a line through the center of the common feature. (The fold usually strikes the lower edge of the paper about an inch from the corner and the right edge about one-half inch from the top.) Place the folded sketch over the other so that half the common feature will be visible on each sketch, and with this common feature as a pivot turn the right sketch until the arrows of both sketches are parallel. The crest and other features of the two sketches should meet approximately along the edges of the fold. The section of the right sketch folded under will depict the identical terrain it covers on the left sketch. (Plate 48.)

As landscape sketches are made rapidly and with a free hand, some adjustment of data will usually be necessary to secure unbroken lines where the sketches meet. The joining should be checked on the ground and corrections made without hesitation.

When several joined sketches are necessary to show the location of related targets, each sketch should be complete in itself with reference points, deflections, etc.

Other Methods of Panoramic Sketching.

There are several other methods used in the instruction of beginners in landscape sketching. Many of these require special apparatus not always available for use in the field.

One system requires a frame bearing a number of vertical and horizontal cross wires which is placed on the ground at such a distance before the eye as to intercept

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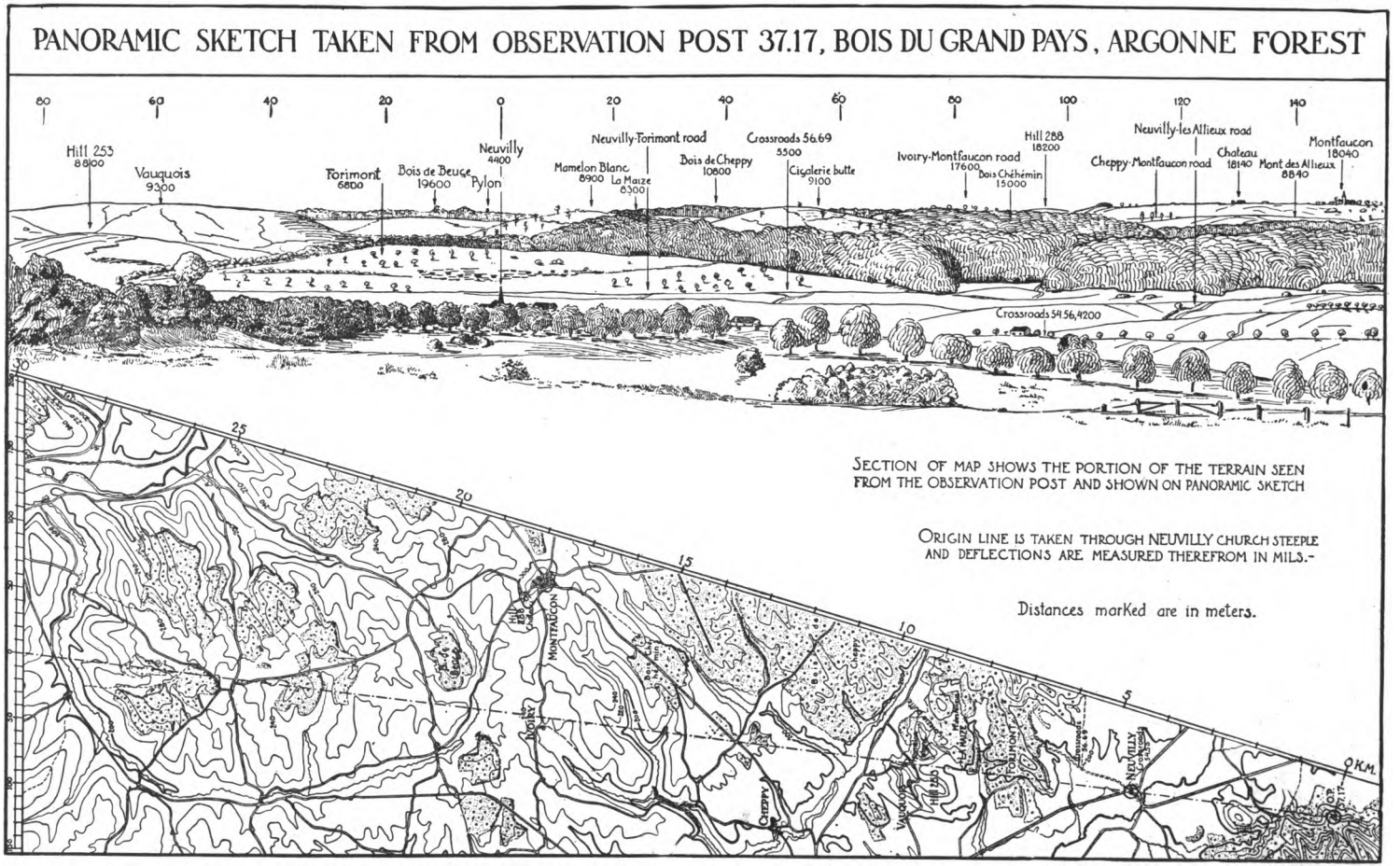

PLATE 49.

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the sector to be sketched. The paper used is ruled in rectangles corresponding exactly to those of the wires of the frame. This method is accurate, but in practice has been found to develop a tendency towards filling in each rectangle with minute details. This results in slow, painstaking work, instead of the rapid free-hand sketching essential in reconnaissance.

Another method of use in learning to sketch is the following: A piece of wire gauze of mesh large enough to admit the point of a pencil is cut exactly the size of the paper used. To locate the critical points of the landscape on the paper, hold the gauze out before the eye, orienting it on the main reference point or other selected features of the landscape. Place the pencil point in the gauze at the feature to be recorded, lay the gauze on the paper, thus locating this point. Do the same for the other prominent features of the terrain. It will be found advisable to locate the

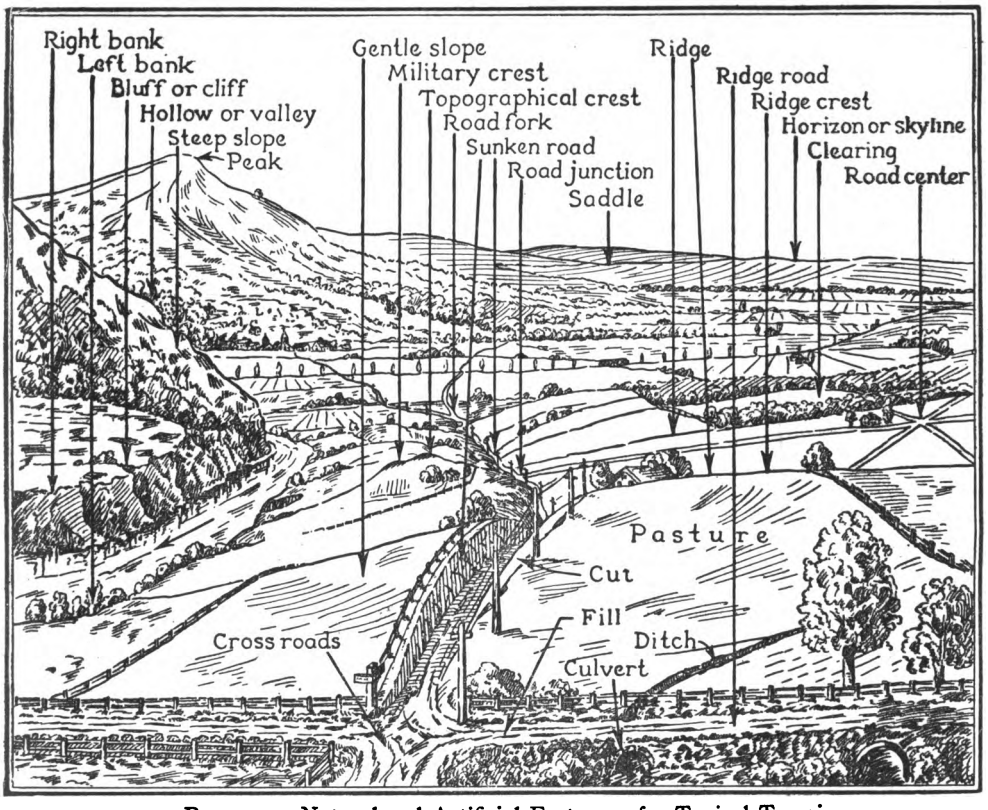

PLATE 50.—Natural and Artificial Features of a Typical Terrain.

points along the skyline and complete this portion of the sketch first. Then locate and sketch in the features of the middle and foreground. The gauze must be carefully oriented every time a point is located for transfer to the paper. For this purpose permanent orientation marks should be placed on the gauze. A string attached to the center and held in the teeth will help in re-orientation. This method will be of assistance to men who find difficulty in transferring points from the upper edge of the paper to the proper place in the sketch. The principle is very simple, and the result should be an accurate sketch. This scheme does not demand specially ruled paper and no apparatus beyond the gauze.

These two methods are mentioned as of possible interest to encourage men who find landscape sketching difficult at first. The confidence engendered by the results attained with the use of these or similar aids to sketching, will soon enable a man to draw with no equipment other than pad, pencil and eye.

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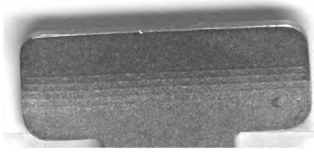

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